US008248457B2

(12) United States Patent
Goldstein et al.

(10) Patent No.: US 8,248,457 B2
(45) Date of Patent: Aug. 21, 2012

(54) **OPTICAL DEVICE**

(75) Inventors: **Michael D. Goldstein**, Herzelia Pituach (IL); **Avi Yaron**, Givat Shmuel (IL)

(73) Assignee: **Visionsense, Ltd.**, Petah Tikva (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 824 days.

(21) Appl. No.: **09/785,791**

(22) Filed: **Feb. 16, 2001**

(65) **Prior Publication Data**

US 2001/0033326 A1 Oct. 25, 2001

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/257,850, filed on Feb. 25, 1999, now Pat. No. 6,396,873, and a continuation-in-part of application No. 09/699,624, filed on Oct. 30, 2000, now Pat. No. 7,154,527.

(51) **Int. Cl.**
H04N 13/00 (2006.01)

(52) **U.S. Cl.** **348/42**; 348/49; 348/57; 348/46; 348/51; 348/43; 348/44; 348/59; 348/45; 348/54; 600/166; 600/109; 250/201.8

(58) **Field of Classification Search** 348/42, 348/49, 57, 46, 51, 43–44, 59, 45, 54, 70, 348/208, 65–66, 61, 69; 600/111, 166, 109; 250/201.7, 201.8; 359/824, 813, 826, 823; 356/4.04; 396/113
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,639,653 A		5/1953	Fischer	95/18
3,932,699 A		1/1976	Tripp	
4,414,470 A		11/1983	Nakaoka	250/204
4,437,764 A		3/1984	Levine et al.	358/44
4,873,572 A		10/1989	Miyazaki et al.	358/98
4,945,407 A		7/1990	Winnek	
4,959,641 A		9/1990	Bass et al.	340/700
5,034,805 A		7/1991	Ishizaka	358/44
5,076,687 A	*	12/1991	Adelson	356/4.04
5,121,452 A		6/1992	Stowe et al.	
5,233,416 A		8/1993	Inoue	358/98
5,313,306 A	*	5/1994	Kuban et al.	348/65
5,428,386 A		6/1995	D'Alfonso et al.	348/45
5,490,015 A	*	2/1996	Umeyama et al.	359/824
5,522,789 A	*	6/1996	Takahashi	600/166
5,527,263 A		6/1996	Zobel et al.	600/166

(Continued)

FOREIGN PATENT DOCUMENTS

CA 2157073 6/1996

(Continued)

OTHER PUBLICATIONS

Handbook of Optics, vol. 2, McGraw-Hill Inc., 1995, p. 15.24, Norman Greenberg.

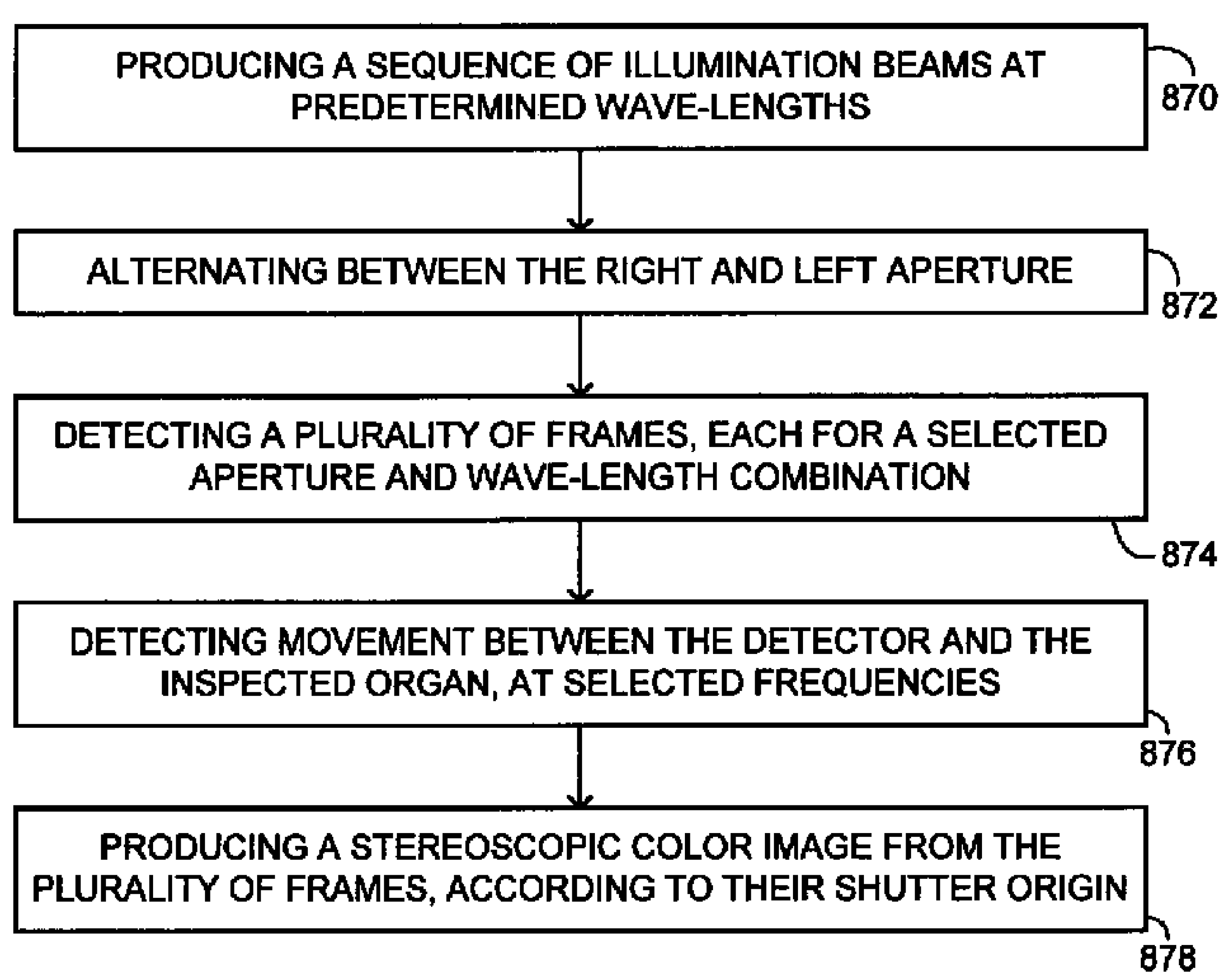
Primary Examiner — Shawn An

(74) *Attorney, Agent, or Firm* — Merchant & Gould P.C.

(57) **ABSTRACT**

A stereoscopic device including a sensor assembly for detecting a sequence of stereoscopic images of an object, a movement detector for detecting the movements of the sensor assembly relative to the object, and a processing unit connected to the sensor assembly and to the movement detector, wherein the processing unit selects portions of the stereoscopic images, according to a signal received from the movement detector, thereby producing a visually stable sequence of display images.

34 Claims, 26 Drawing Sheets



U.S. PATENT DOCUMENTS

5,552,840	A		9/1996	Ishii et al.	348/751
5,588,948	A		12/1996	Takahashi et al.	600/111
5,594,497	A		1/1997	Ahern et al.	348/71
5,603,687	A		2/1997	Hori et al.	600/166
5,604,531	A		2/1997	Iddan et al.	
5,606,455	A		2/1997	Eichenlaub	359/463
5,613,936	A		3/1997	Czarnek et al.	600/166
5,743,846	A		4/1998	Takahashi et al.	600/166
5,743,847	A		4/1998	Nakamura et al.	600/166
5,751,341	A		5/1998	Chaleki et al.	348/65
5,760,827	A		6/1998	Faris	348/42
5,776,049	A		7/1998	Takahashi	600/111
5,796,427	A	*	8/1998	Suzuki	348/208.6
5,800,341	A	*	9/1998	McKenna et al.	600/109
5,812,187	A	*	9/1998	Watanabe	348/70
5,825,534	A		10/1998	Strahle	359/376
5,828,487	A		10/1998	Greening et al.	359/466
5,865,829	A		2/1999	Kitajima	
5,868,664	A		2/1999	Speier et al.	600/112
5,991,074	A		11/1999	Nose et al.	359/465
6,075,555	A	*	6/2000	Street	348/43
6,306,082	B1		10/2001	Takahashi et al.	
6,593,957	B1		7/2003	Christie	

FOREIGN PATENT DOCUMENTS

WO	WO 00/22975	10/1999

* cited by examiner

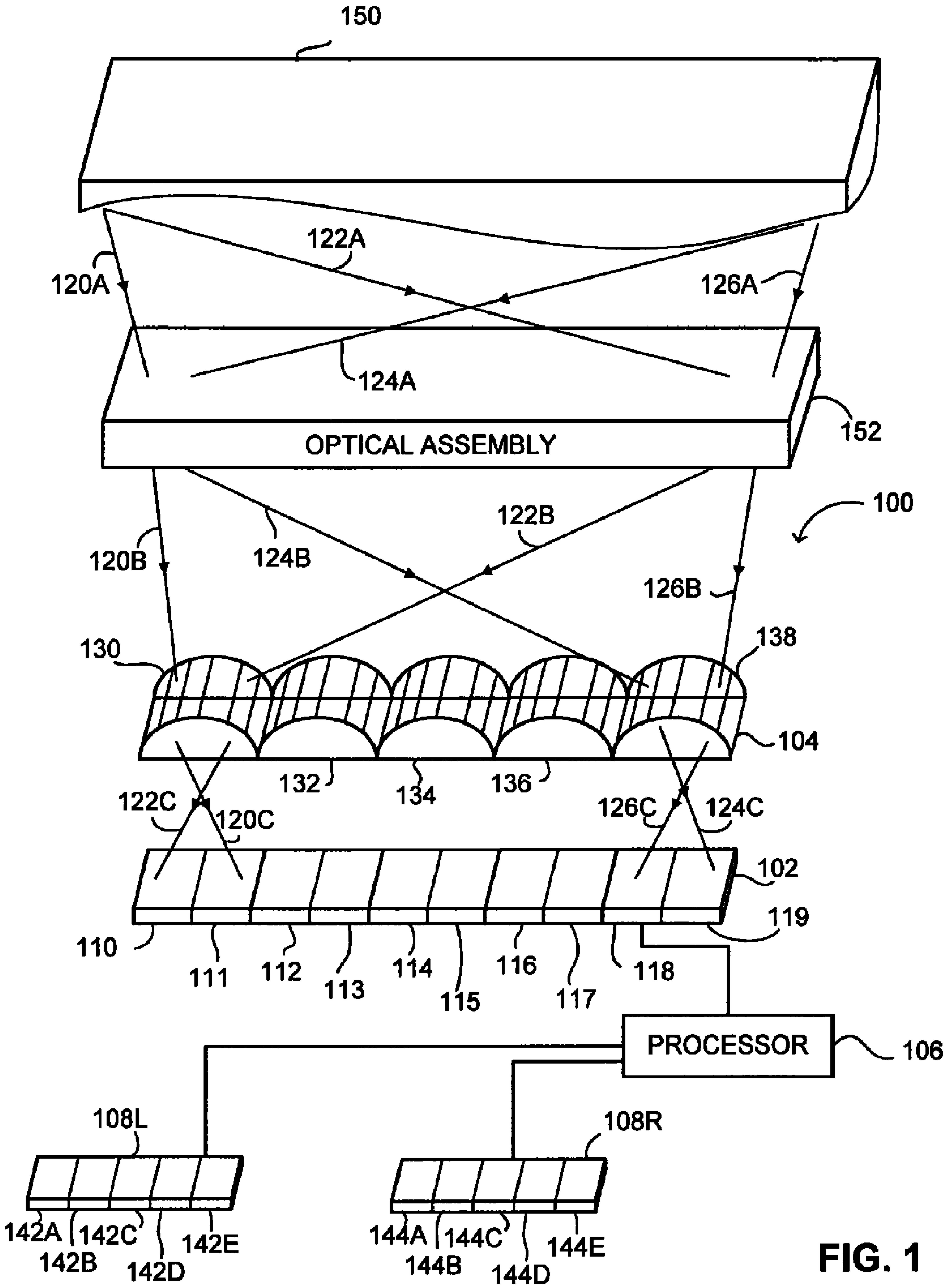

150
122A
120A
126A
124A
OPTICAL ASSEMBLY
152
100
122B
120B
124B
126B
130
138
104
132
134
136
122C
120C
126C
124C
102
119
110
111
112
113
114
115
116
117
118
PROCESSOR
106
108L
108R
142A
142B
142C
142D
142E
144A
144B
144C
144D
144E

FIG. 1

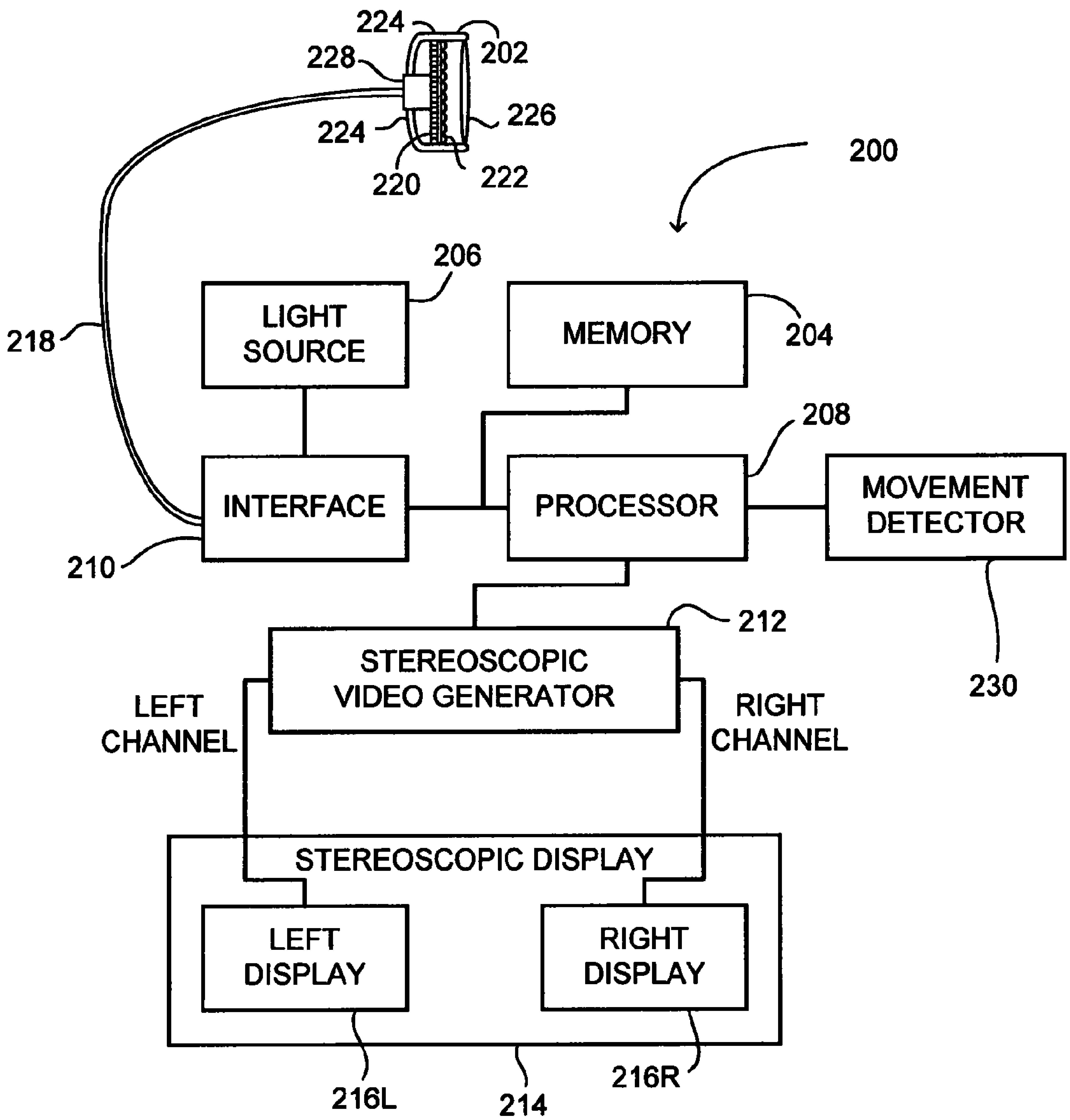

224
228
202
226
224
220
222
200
206
218
LIGHT SOURCE
MEMORY
204
208
INTERFACE
PROCESSOR
MOVEMENT DETECTOR
210
212
STEREOSCOPIC VIDEO GENERATOR
230
LEFT CHANNEL
RIGHT CHANNEL
STEREOSCOPIC DISPLAY
LEFT DISPLAY
RIGHT DISPLAY
216L
214
216R

FIG. 2

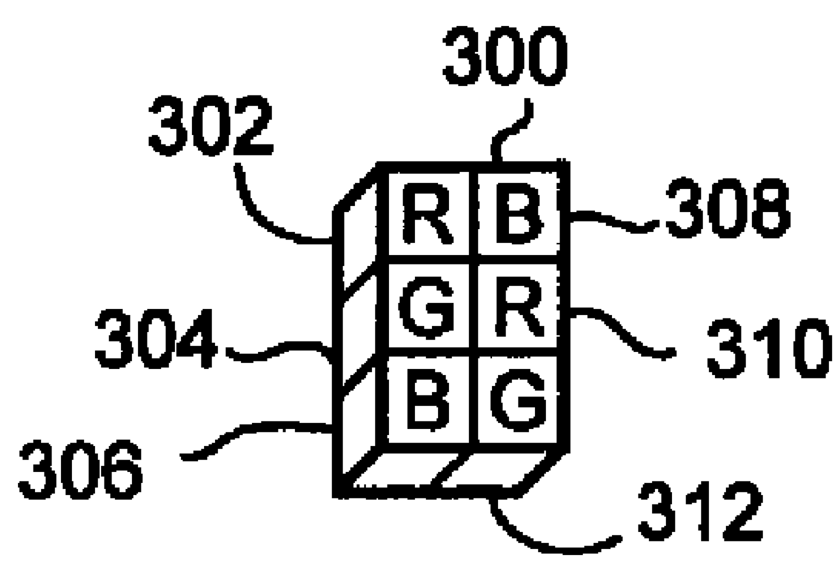


FIG. 3A

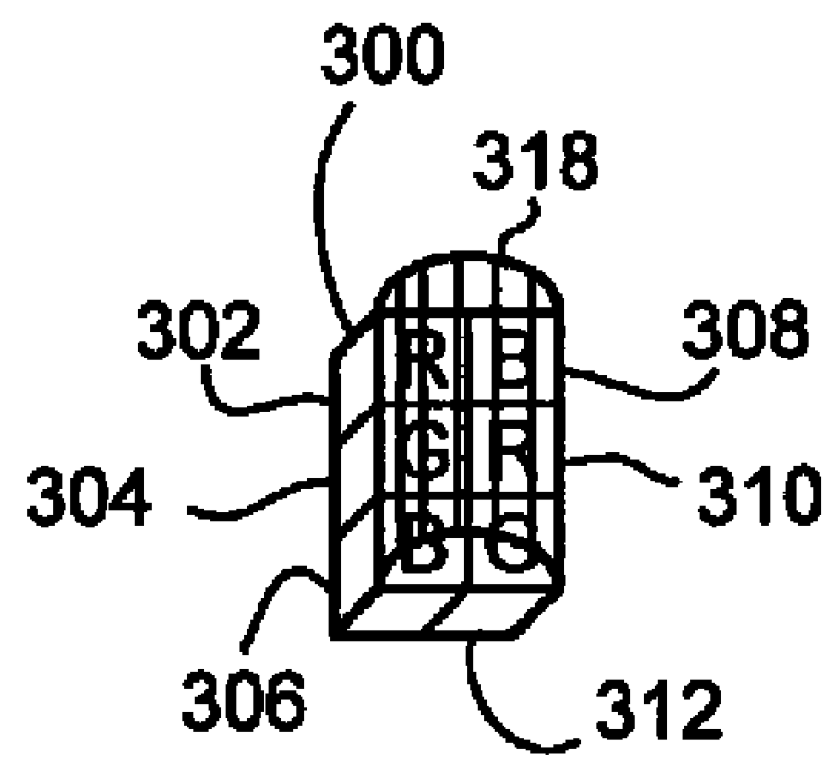


FIG. 3B

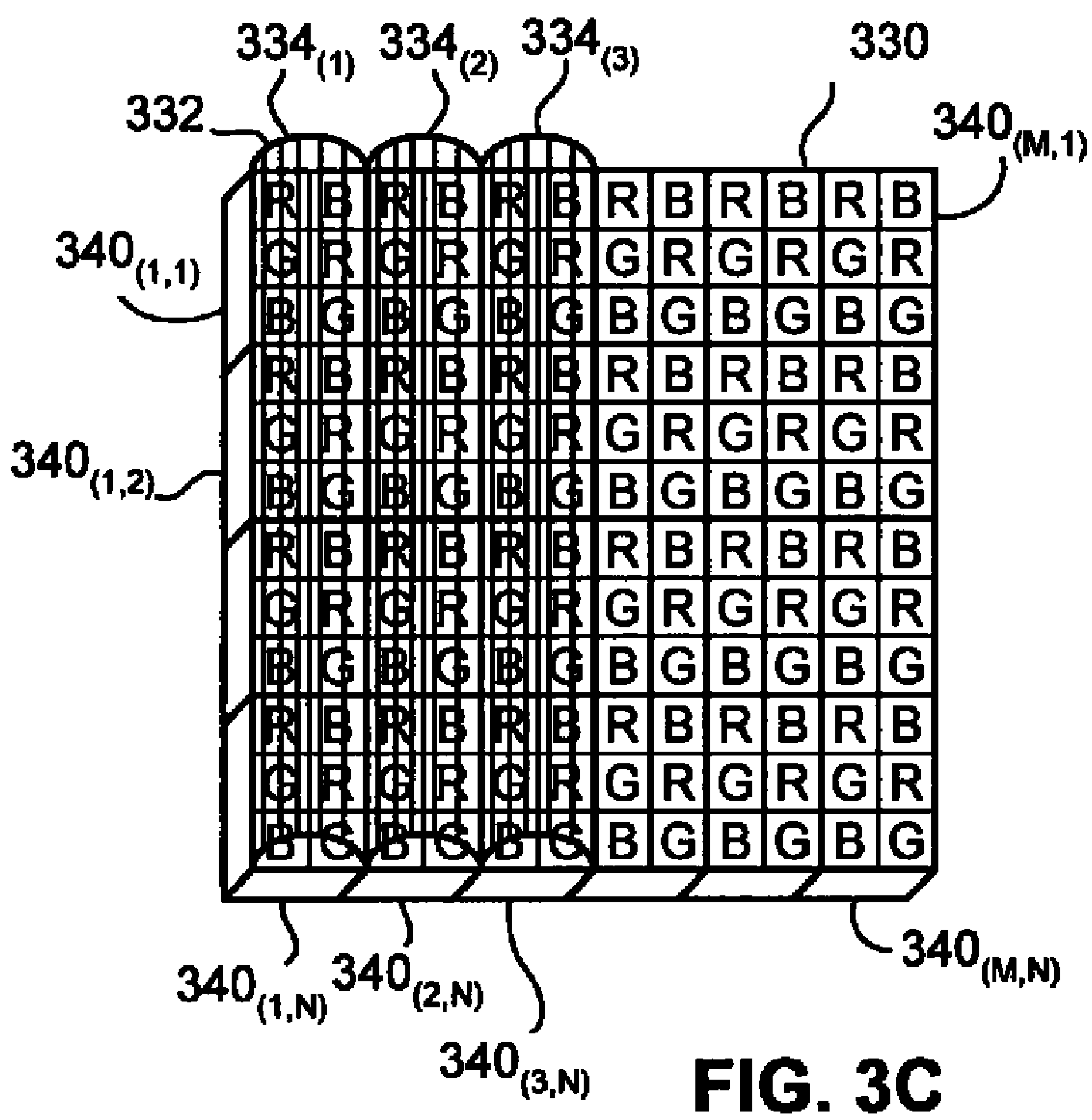


FIG. 3C

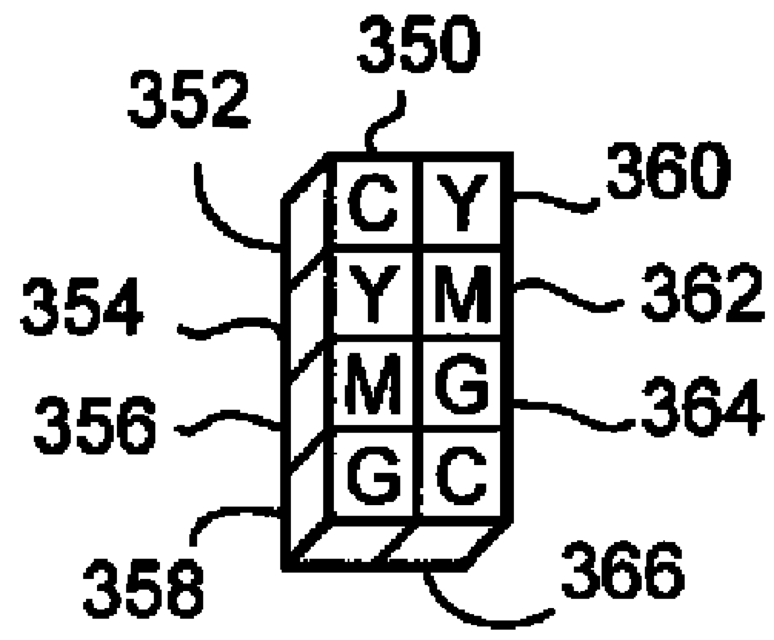


FIG. 4

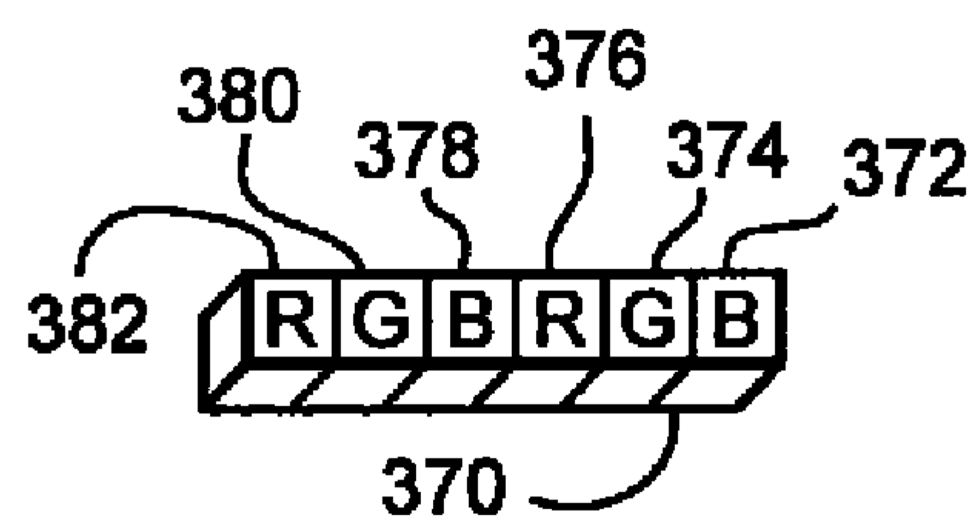


FIG. 5A

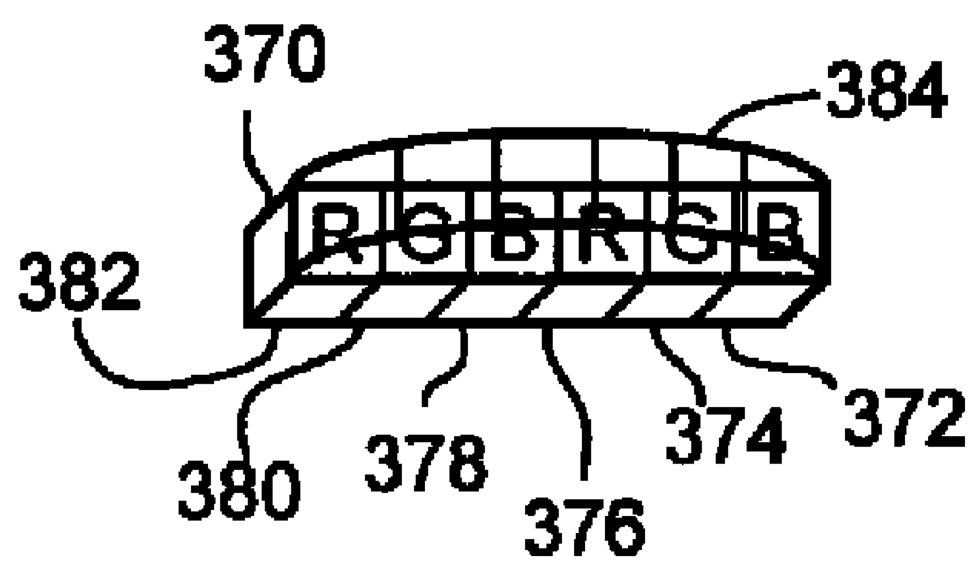


FIG. 5B

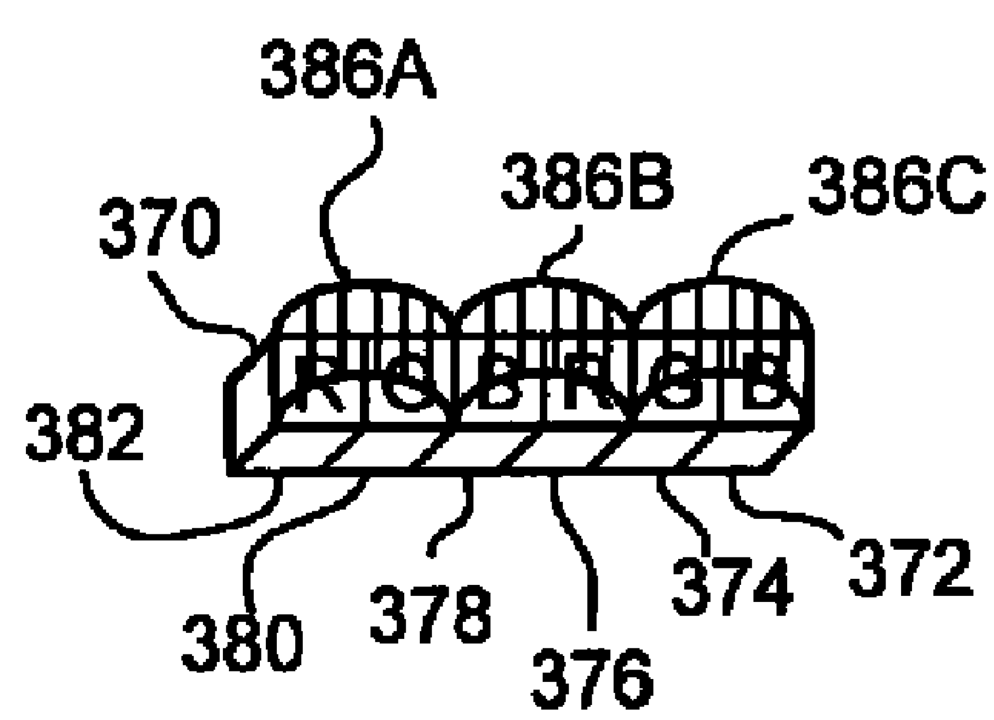


FIG. 5C

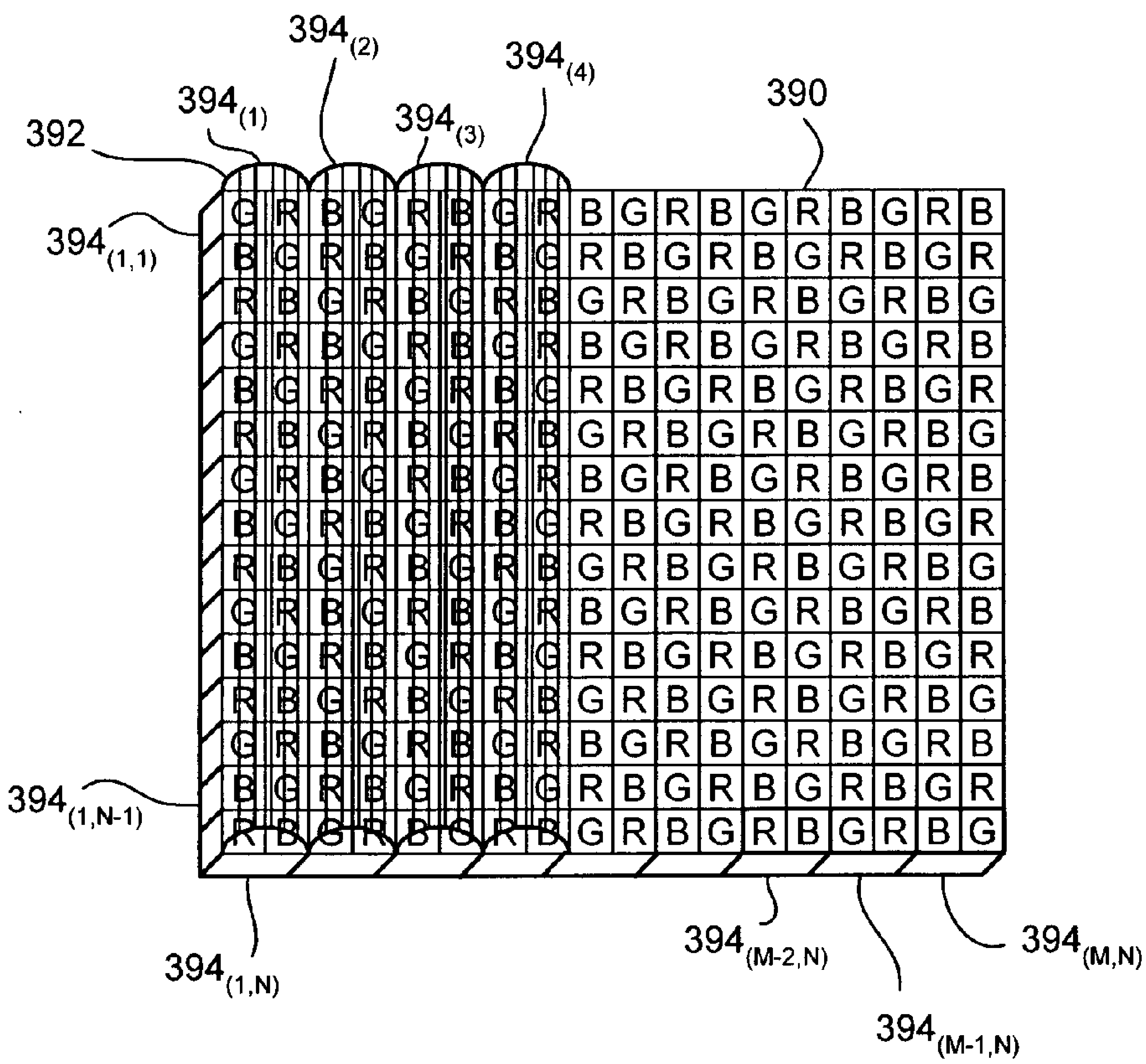

394(2)
394(4)
394(1)
394(3)
390
392
394(1,1)
394(1,N-1)
394(1,N)
394(M-2,N)
394(M,N)
394(M-1,N)

FIG. 6

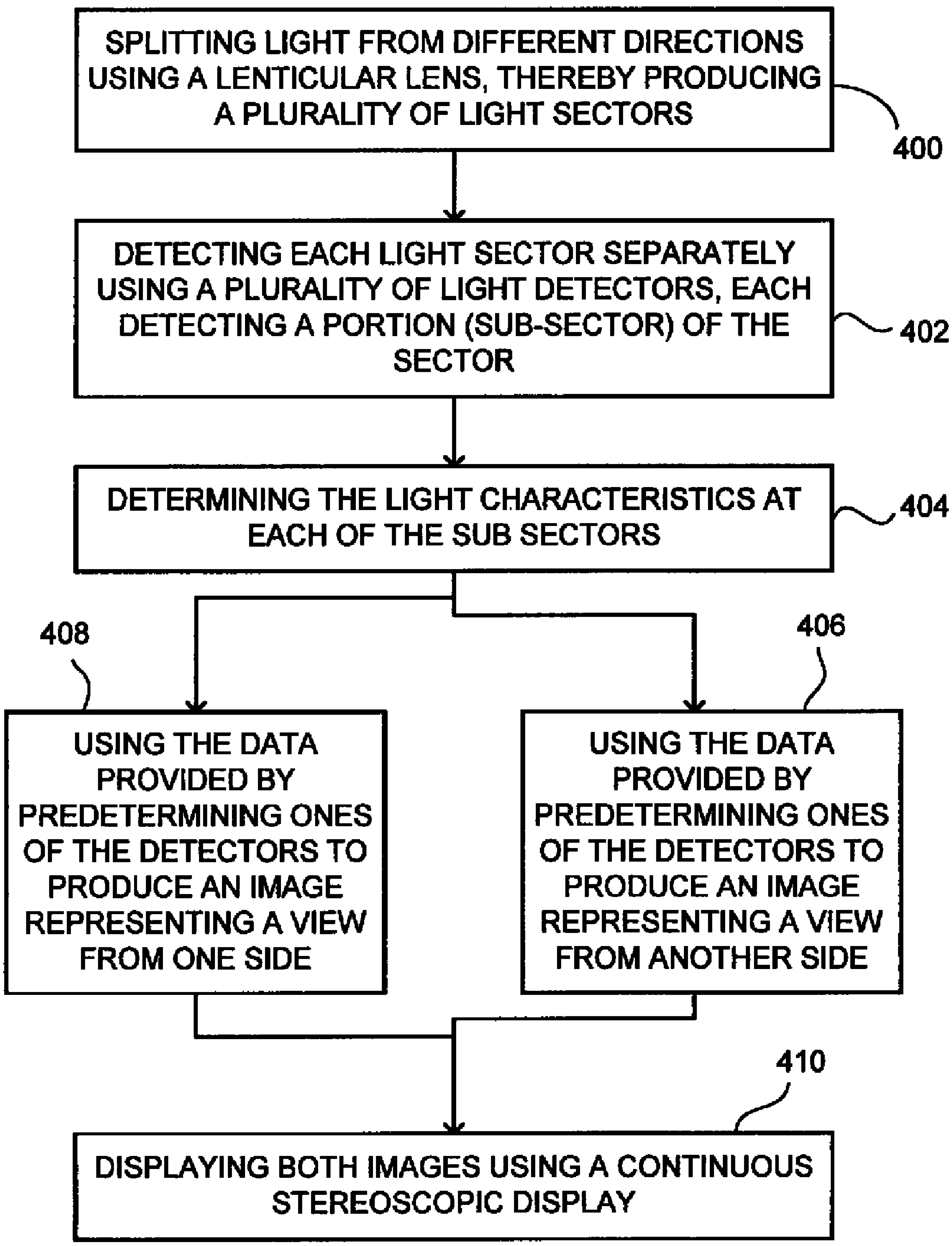

SPLITTING LIGHT FROM DIFFERENT DIRECTIONS USING A LENTICULAR LENS, THEREBY PRODUCING A PLURALITY OF LIGHT SECTORS
400
DETECTING EACH LIGHT SECTOR SEPARATELY USING A PLURALITY OF LIGHT DETECTORS, EACH DETECTING A PORTION (SUB-SECTOR) OF THE SECTOR
402
DETERMINING THE LIGHT CHARACTERISTICS AT EACH OF THE SUB SECTORS
404
408
406
USING THE DATA PROVIDED BY PREDETERMINING ONES OF THE DETECTORS TO PRODUCE AN IMAGE REPRESENTING A VIEW FROM ONE SIDE
USING THE DATA PROVIDED BY PREDETERMINING ONES OF THE DETECTORS TO PRODUCE AN IMAGE REPRESENTING A VIEW FROM ANOTHER SIDE
410
DISPLAYING BOTH IMAGES USING A CONTINUOUS STEREOSCOPIC DISPLAY

FIG. 7A

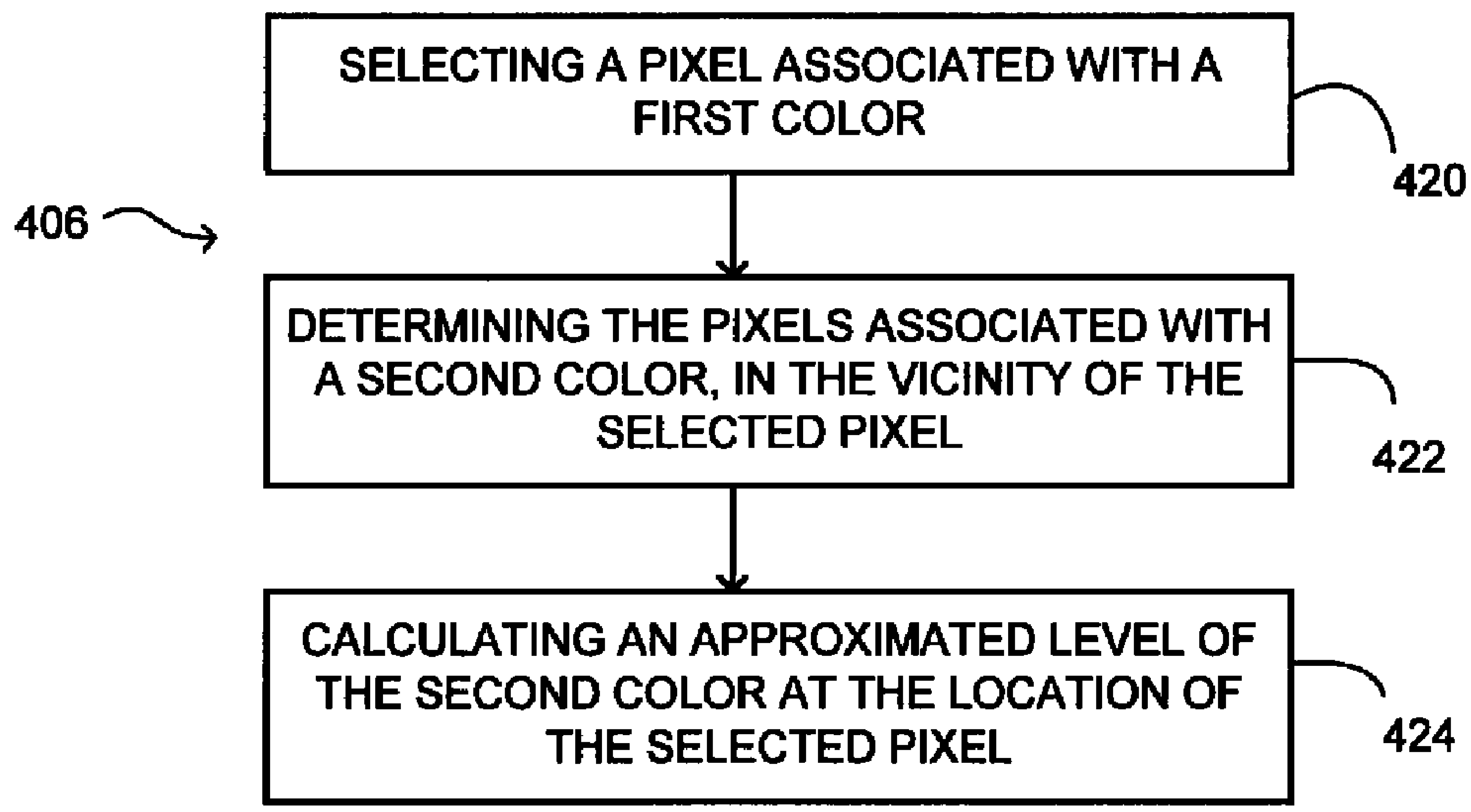

406
SELECTING A PIXEL ASSOCIATED WITH A FIRST COLOR
420
DETERMINING THE PIXELS ASSOCIATED WITH A SECOND COLOR, IN THE VICINITY OF THE SELECTED PIXEL
422
CALCULATING AN APPROXIMATED LEVEL OF THE SECOND COLOR AT THE LOCATION OF THE SELECTED PIXEL
424

FIG. 7B

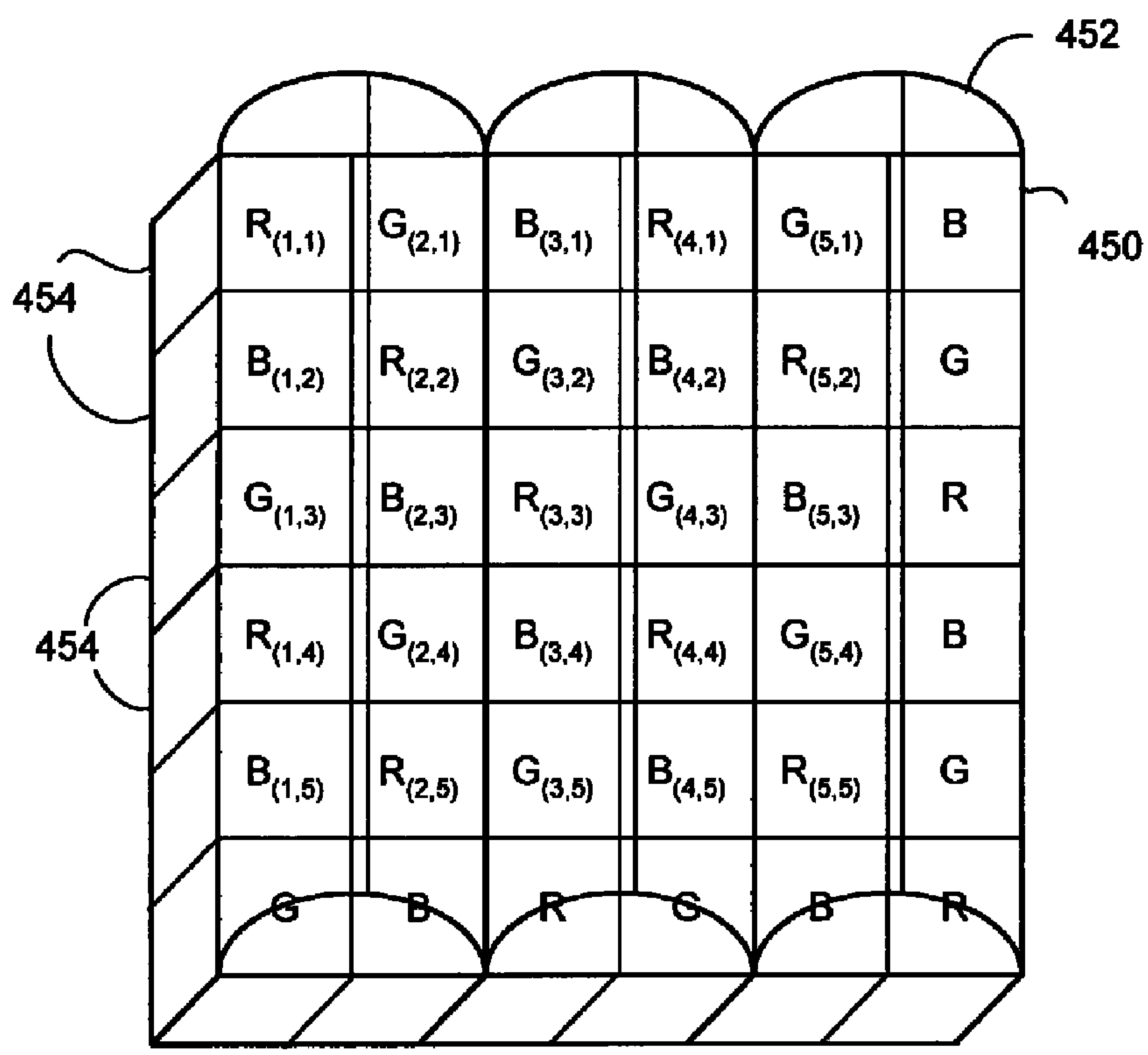

452
450
454
454
R(1,1) G(2,1) B(3,1) R(4,1) G(5,1) B
B(1,2) R(2,2) G(3,2) B(4,2) R(5,2) G
G(1,3) B(2,3) R(3,3) G(4,3) B(5,3) R
R(1,4) G(2,4) B(3,4) R(4,4) G(5,4) B
B(1,5) R(2,5) G(3,5) B(4,5) R(5,5) G
G B R G B R

FIG. 7C

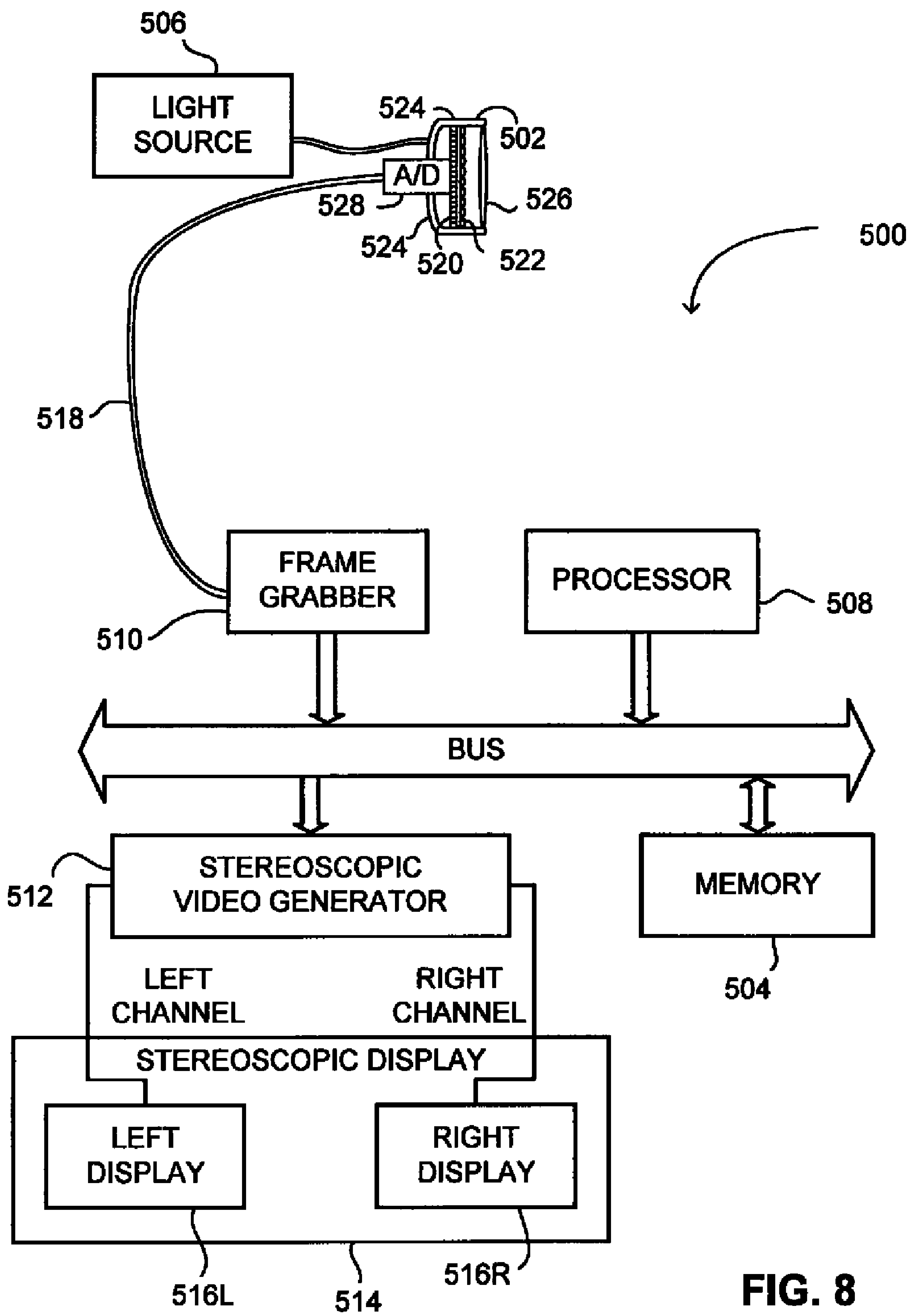

506
LIGHT SOURCE
524
502
A/D
528
526
524
520
522
500
518
FRAME GRABBER
PROCESSOR
508
510
BUS
STEREOSCOPIC VIDEO GENERATOR
512
MEMORY
LEFT CHANNEL
RIGHT CHANNEL
504
STEREOSCOPIC DISPLAY
LEFT DISPLAY
RIGHT DISPLAY
516L
514
516R

FIG. 8

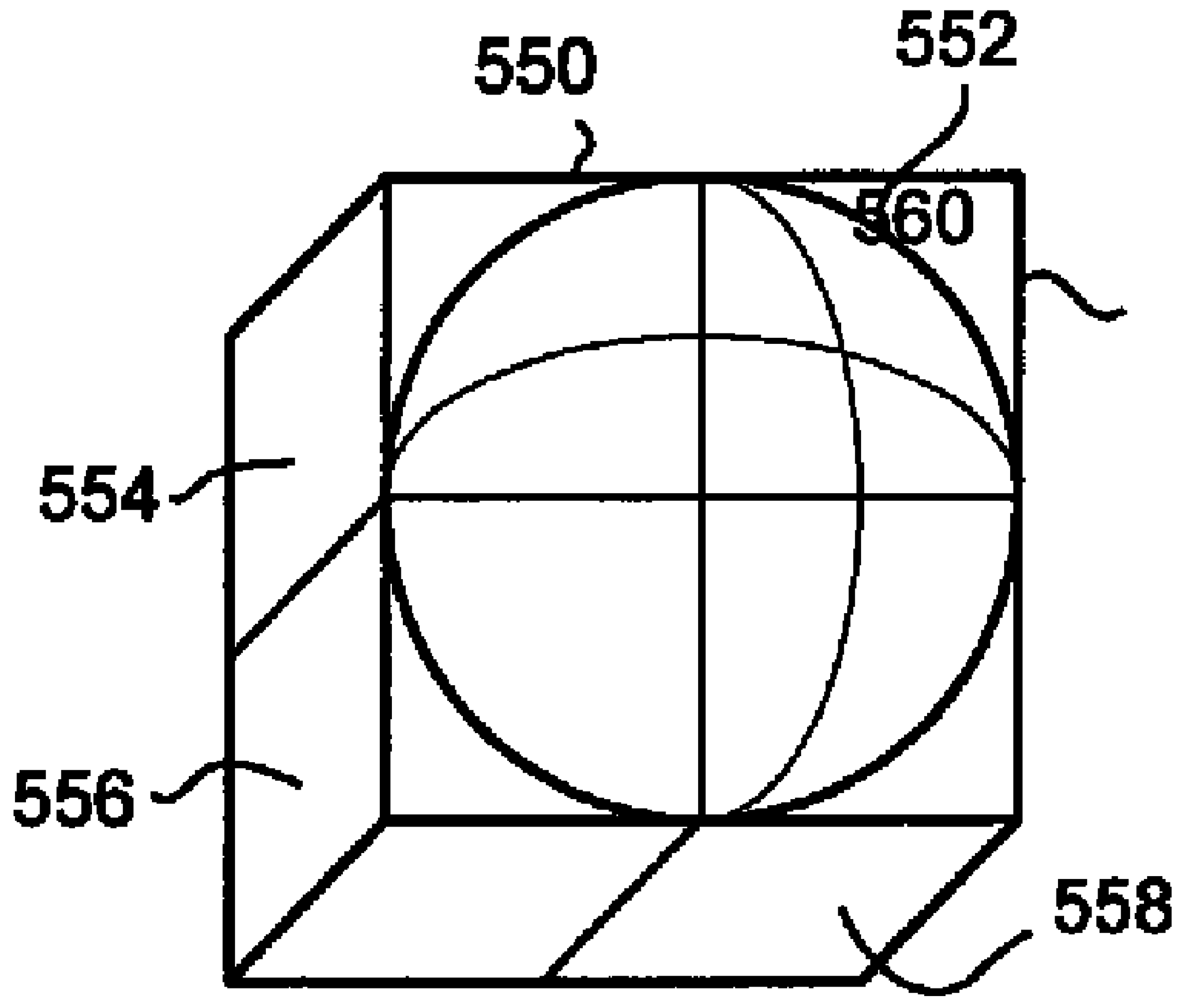


FIG. 9A

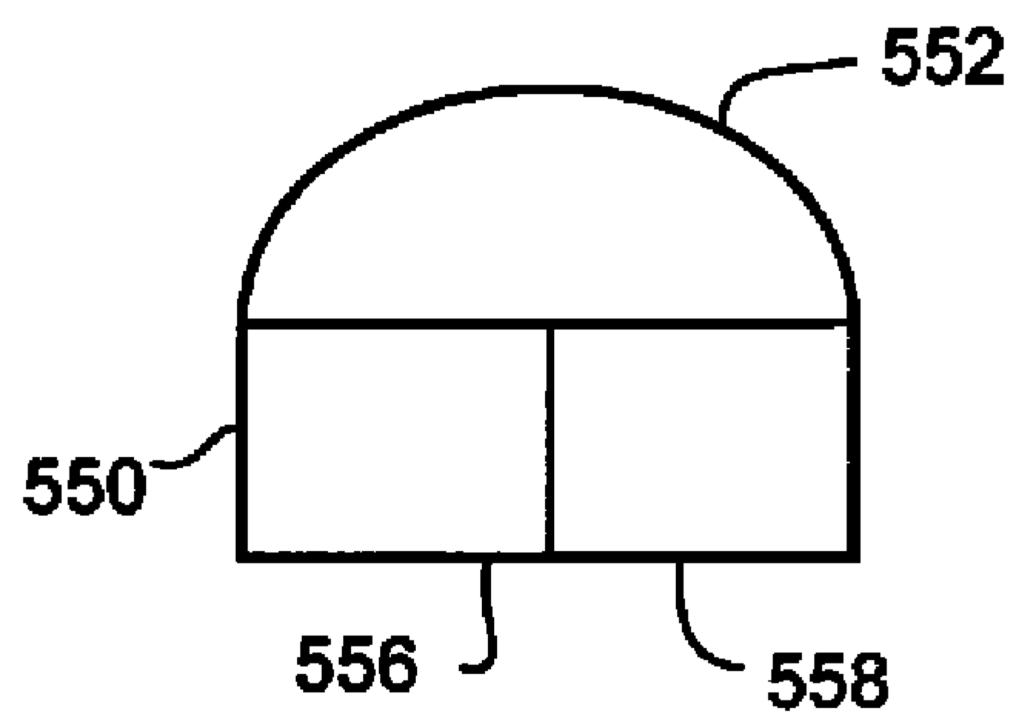


FIG. 9B

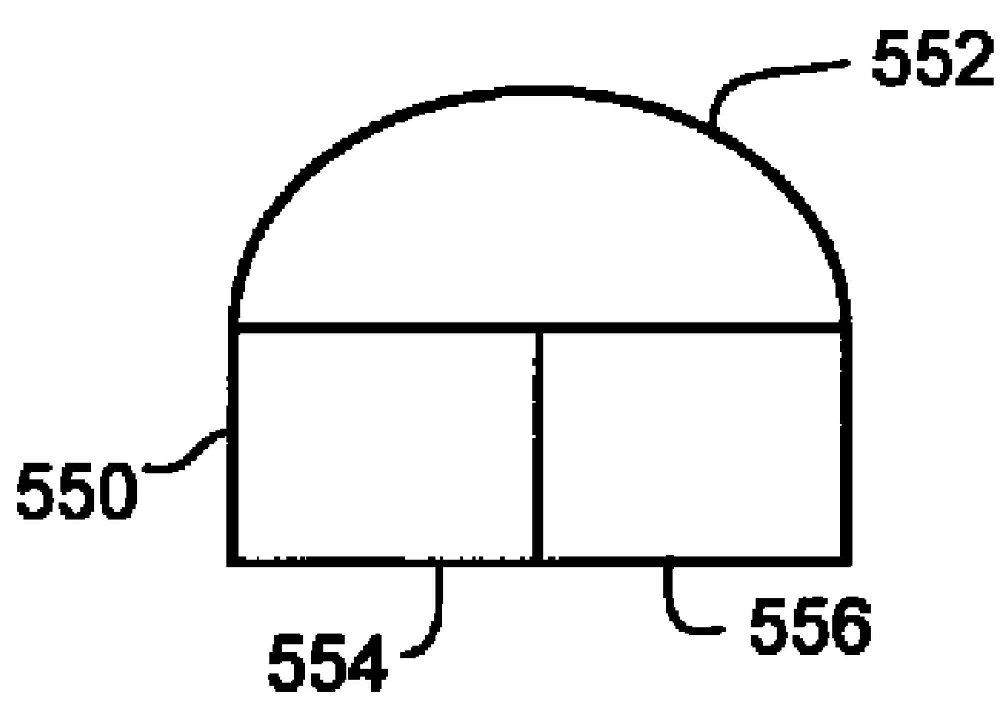


FIG. 9C

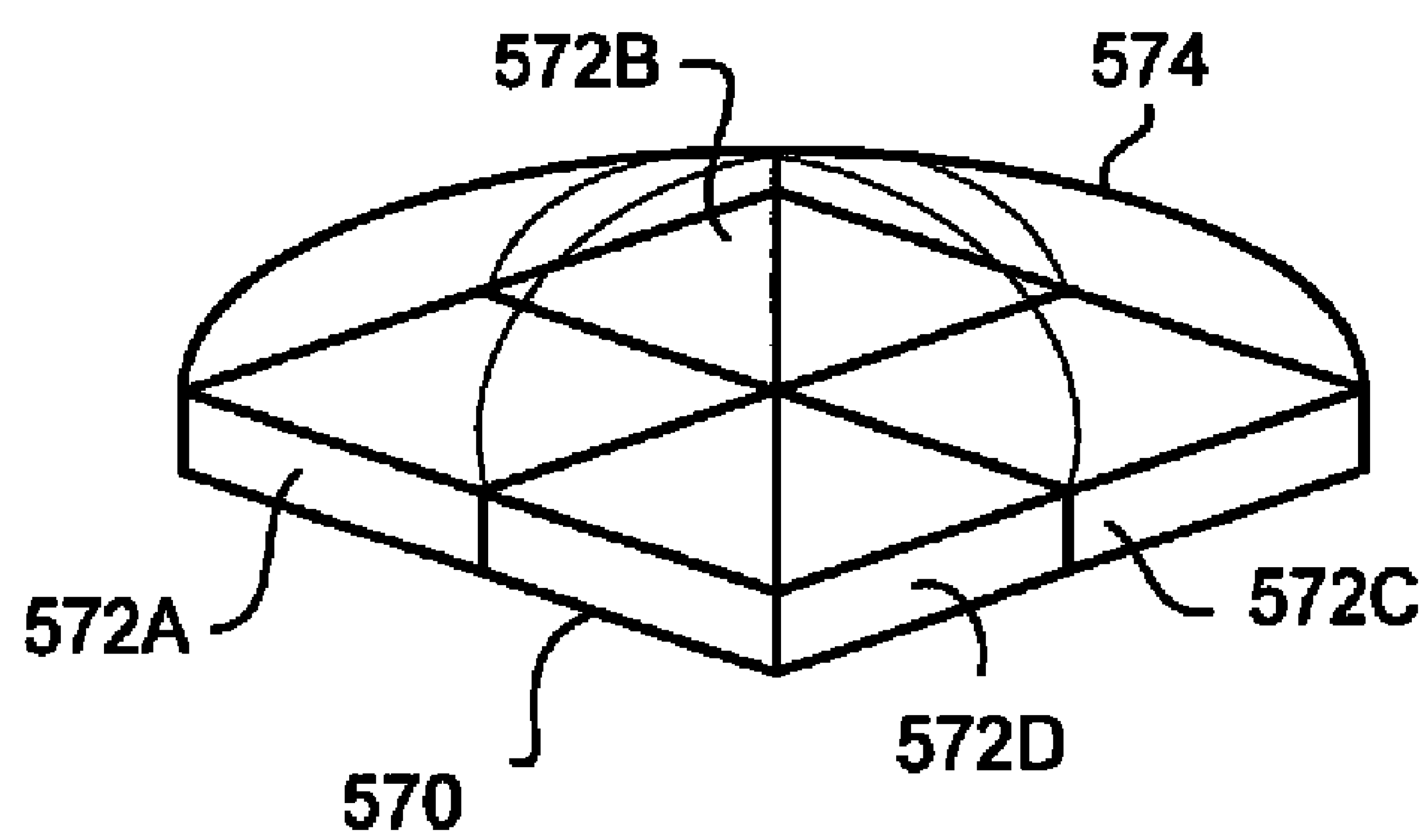


FIG. 10

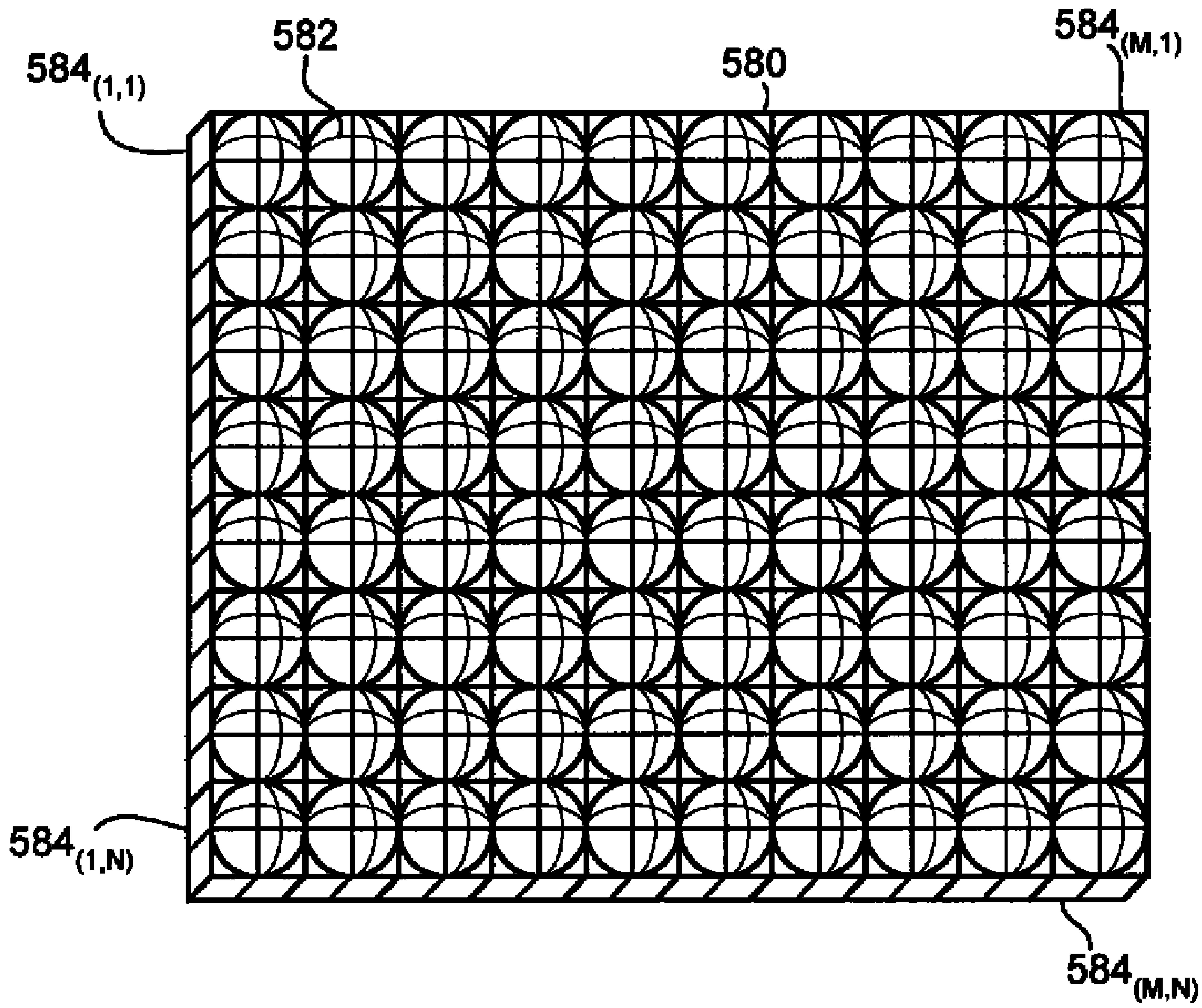


FIG. 11

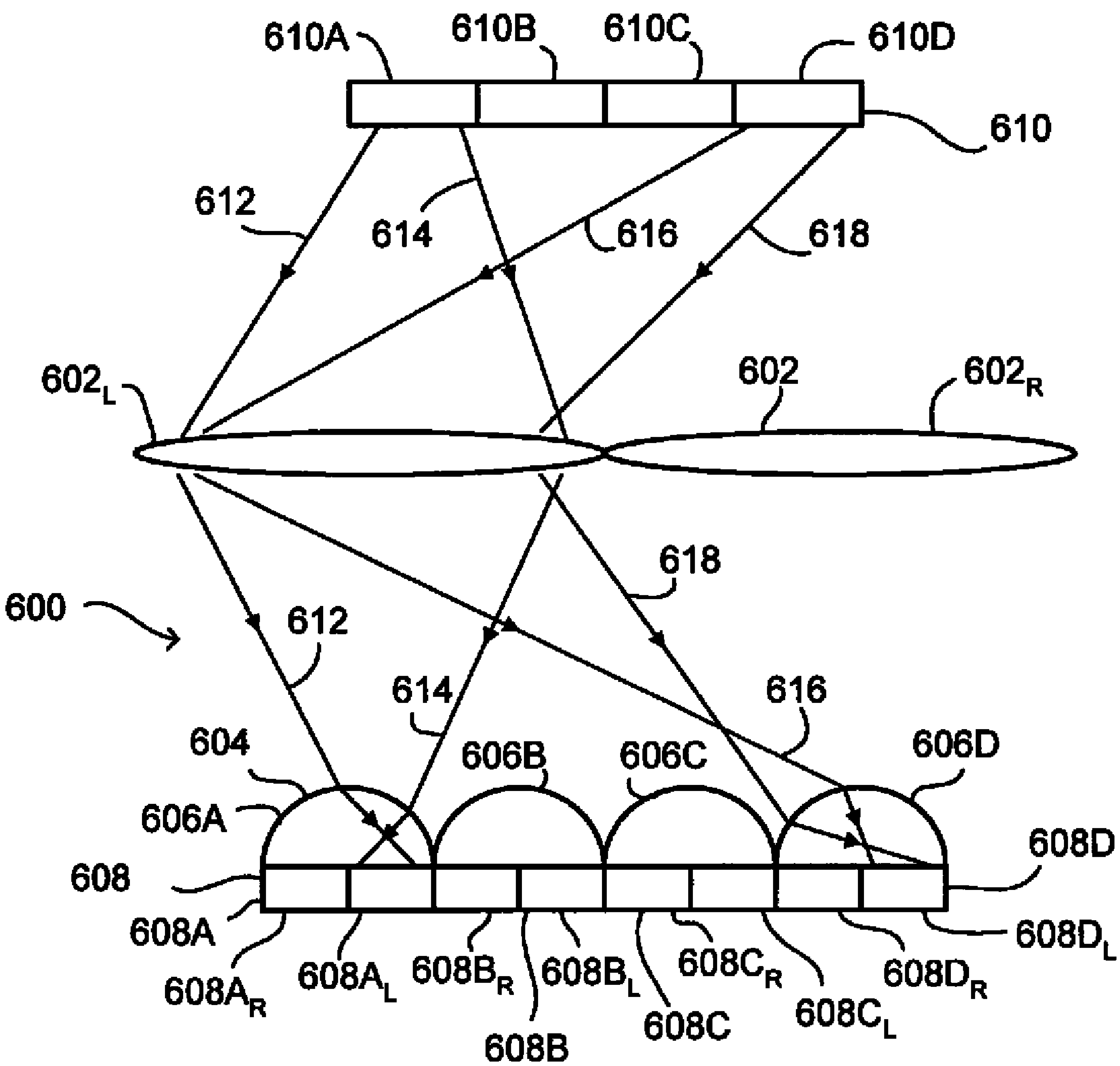

610A
610B
610C
610D
610
612
614
616
618
602L
602
602R
600
618
612
614
616
604
606A
606B
606C
606D
608
608D
608A
608AR
608AL
608BR
608BL
608B
608C
608CR
608CL
608DR
608DL

FIG. 12A

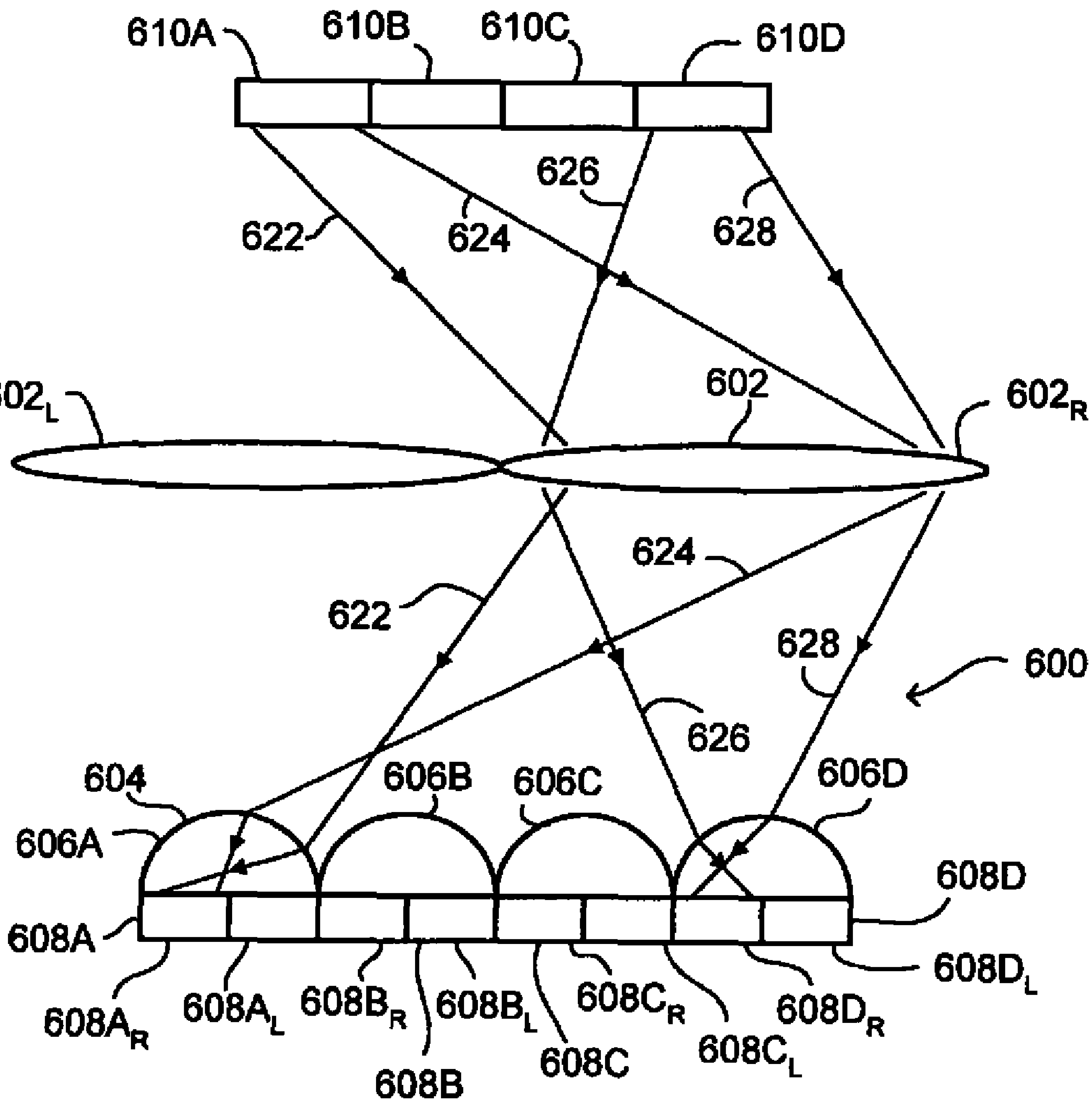

610A
610B
610C
610D
626
622
624
628
602_L
602
602_R
624
622
628
600
626
604
606B
606C
606D
606A
608D
608A
$608D_L$
$608A_R$
$608A_L$
$608B_R$
$608B_L$
$608C_R$
$608D_R$
608C
$608C_L$
608B

FIG. 12B

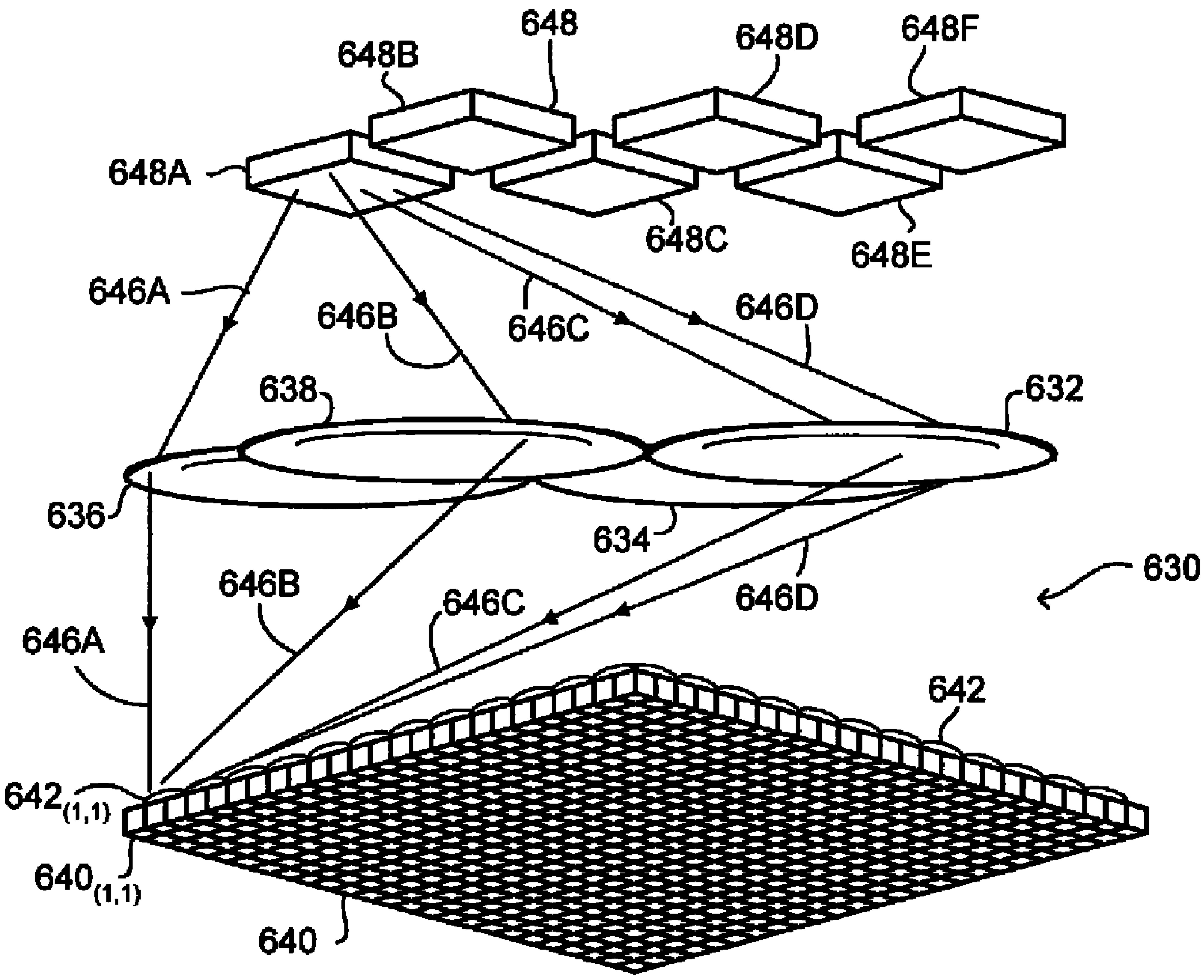

648
648B
648D
648F
648A
648C
648E
646A
646B
646C
646D
638
632
636
634
646B
646C
646D
630
646A
642
$642_{(1,1)}$
$640_{(1,1)}$
640

FIG. 13

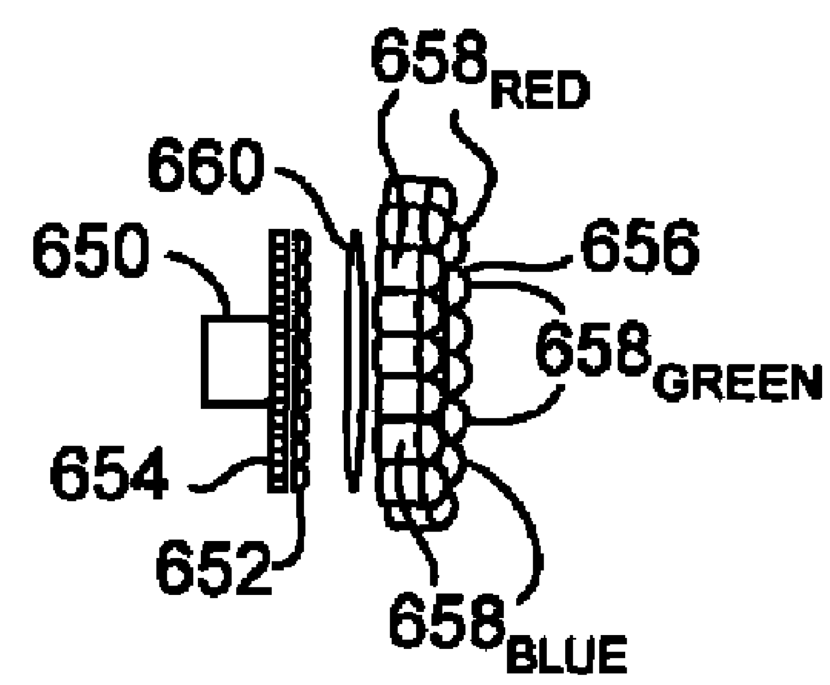


FIG. 14A

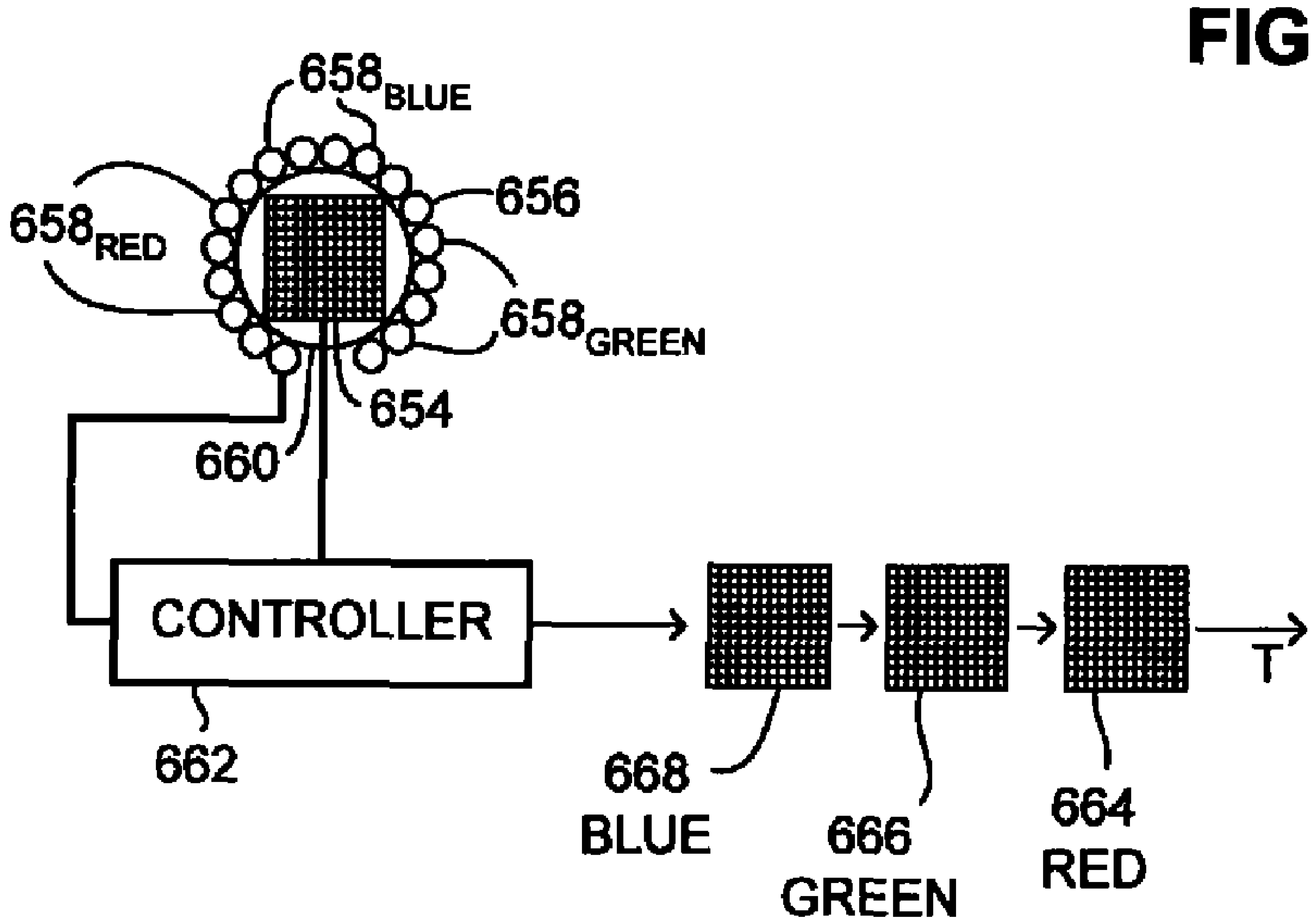


FIG. 14B

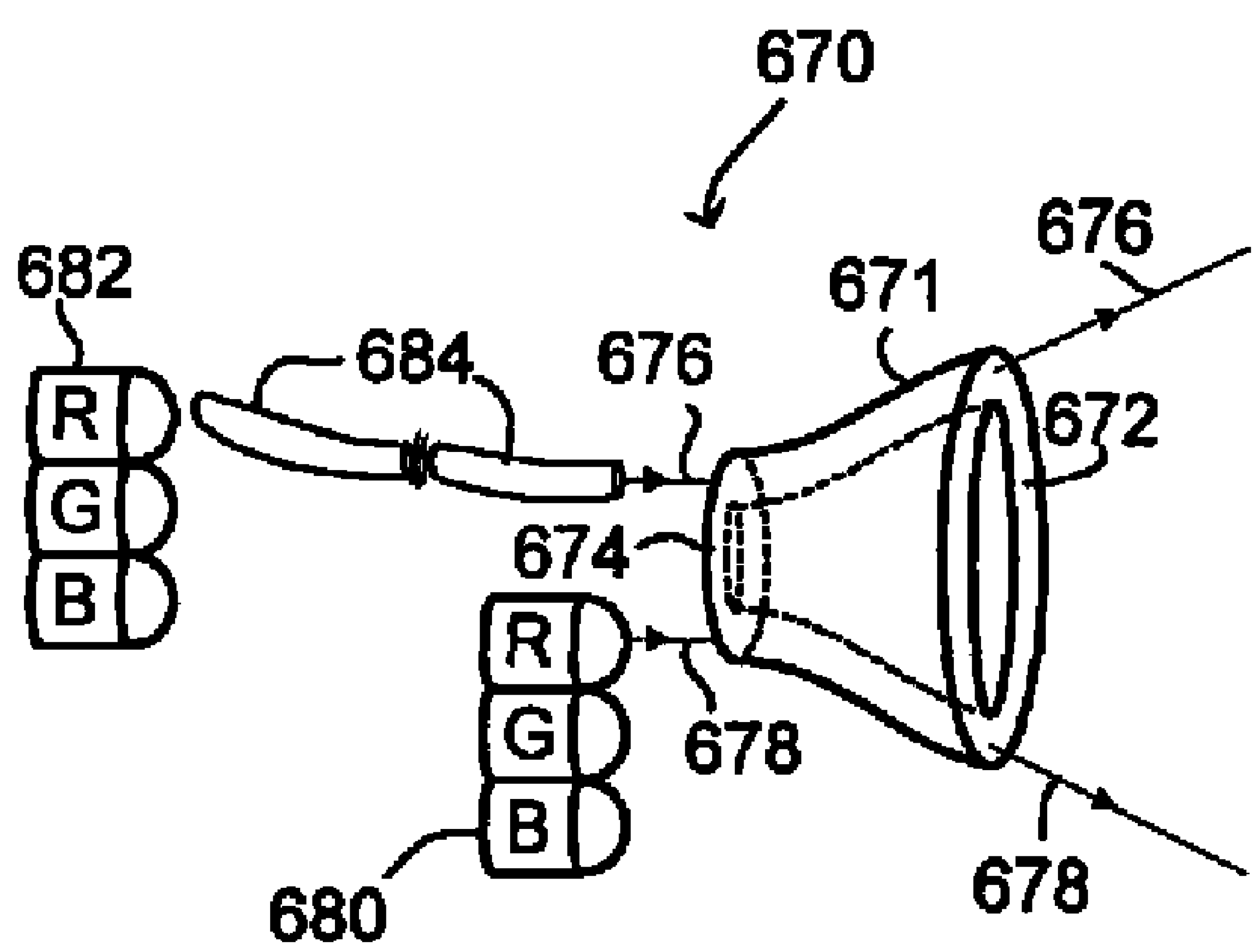
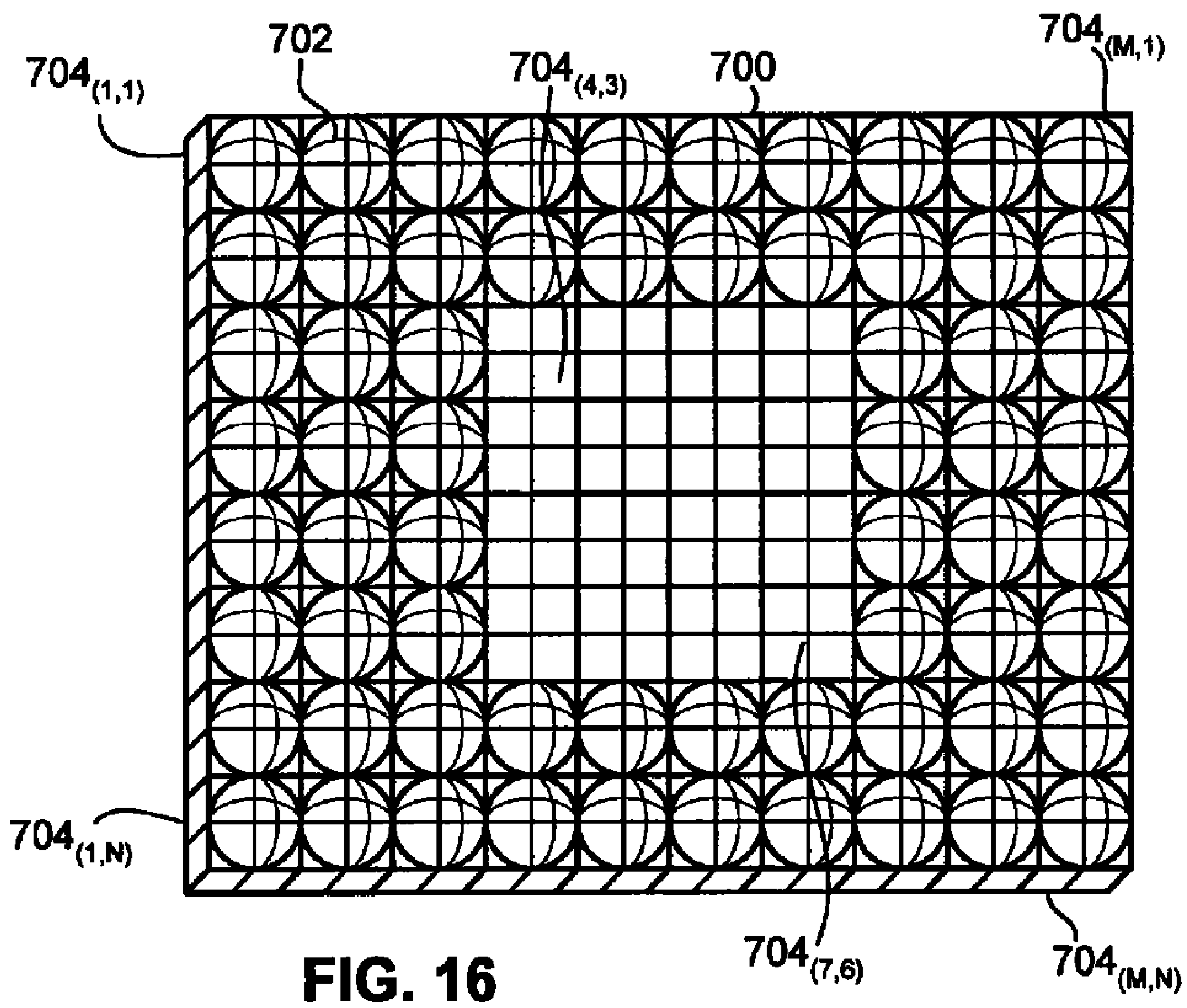
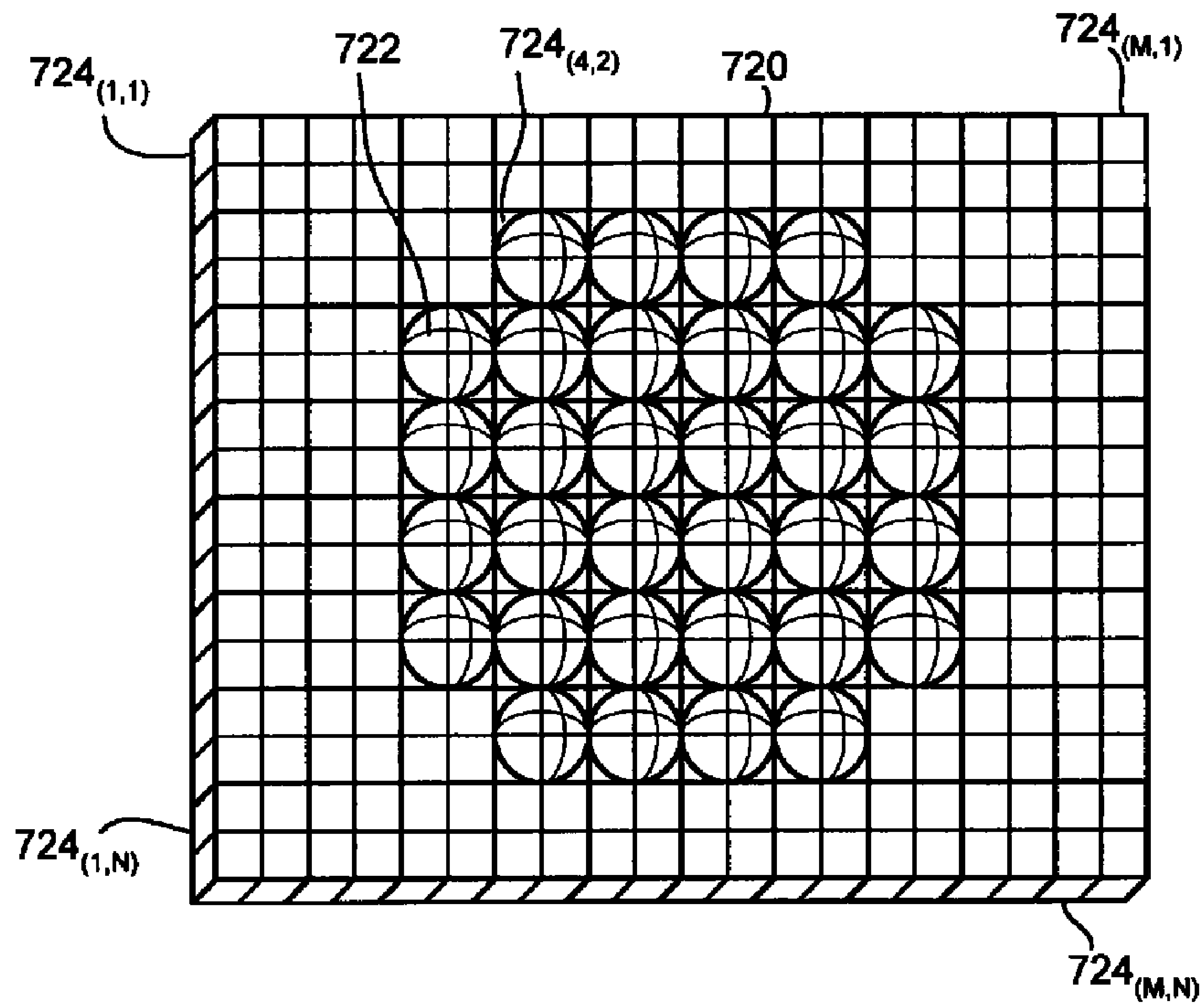


FIG. 15



704(1,1)
702
704(4,3)
700
704(M,1)
704(1,N)
704(7,6)
704(M,N)

FIG. 16



724(1,1)
722
724(4,2)
720
724(M,1)
724(1,N)
724(M,N)

FIG. 17

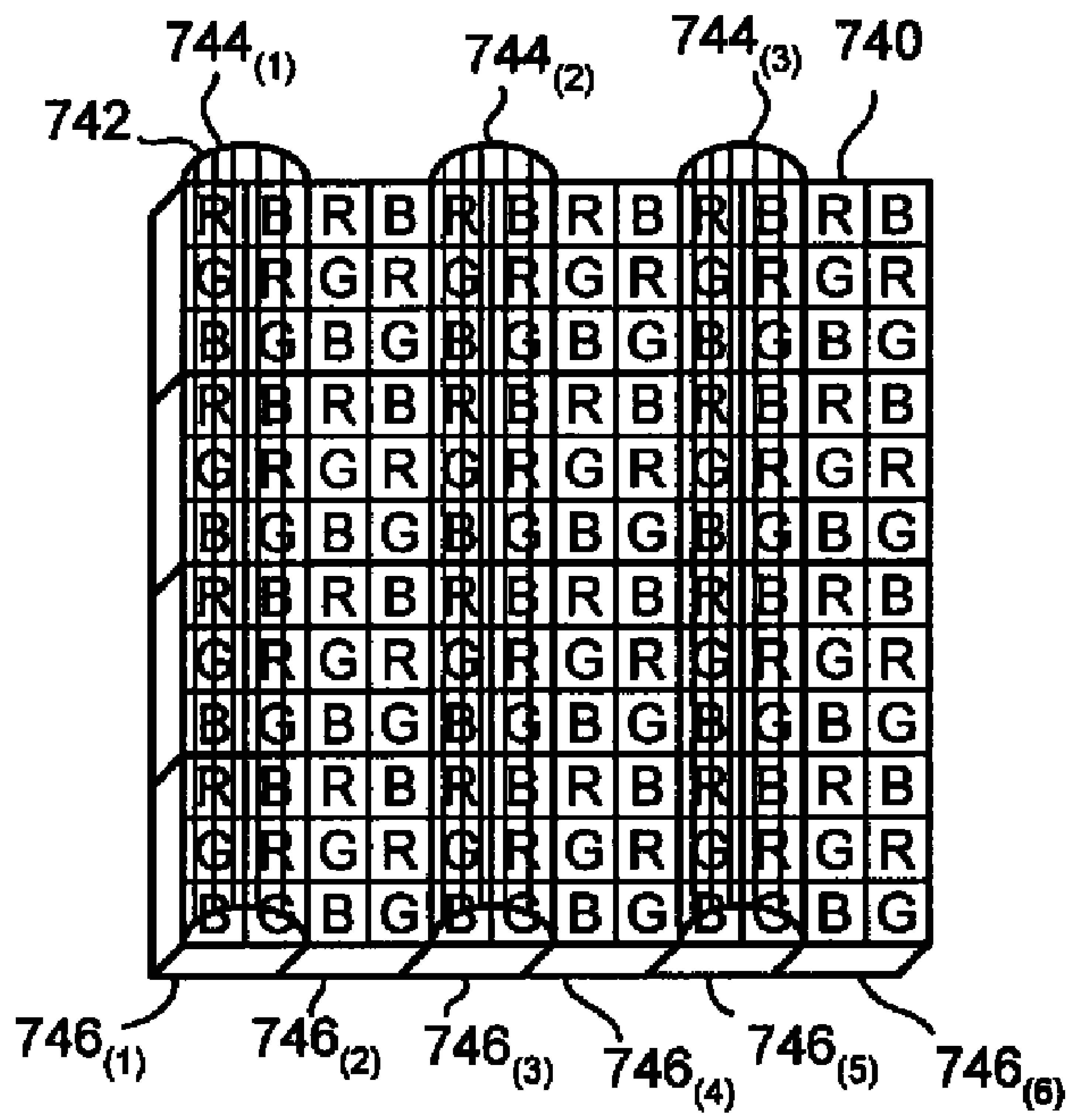

$744_{(1)}$
$744_{(2)}$
$744_{(3)}$
740
742
$746_{(1)}$
$746_{(2)}$
$746_{(3)}$
$746_{(4)}$
$746_{(5)}$
$746_{(6)}$

FIG. 18

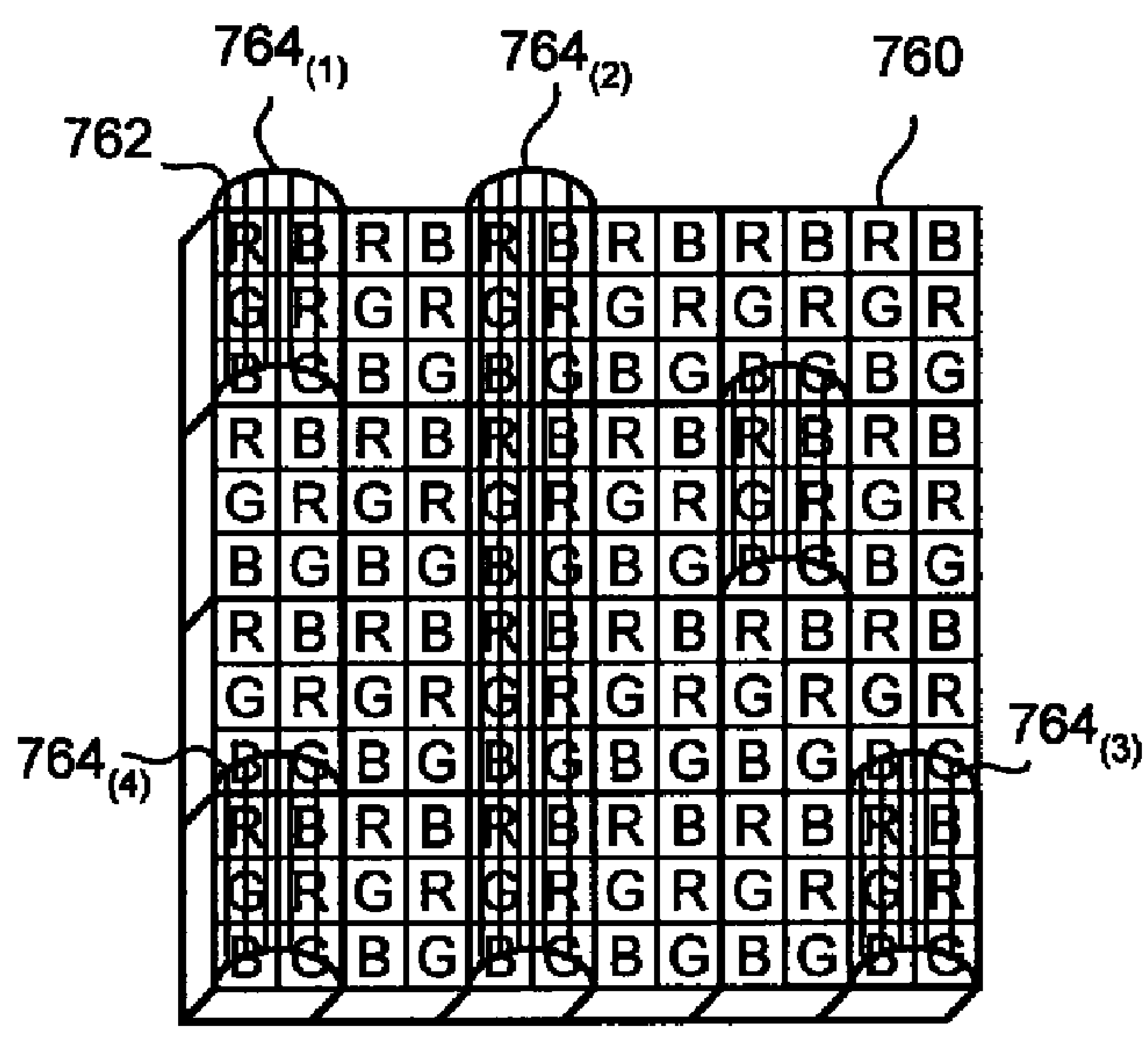

$764_{(1)}$
$764_{(2)}$
760
762
$764_{(4)}$
$764_{(3)}$

FIG. 19

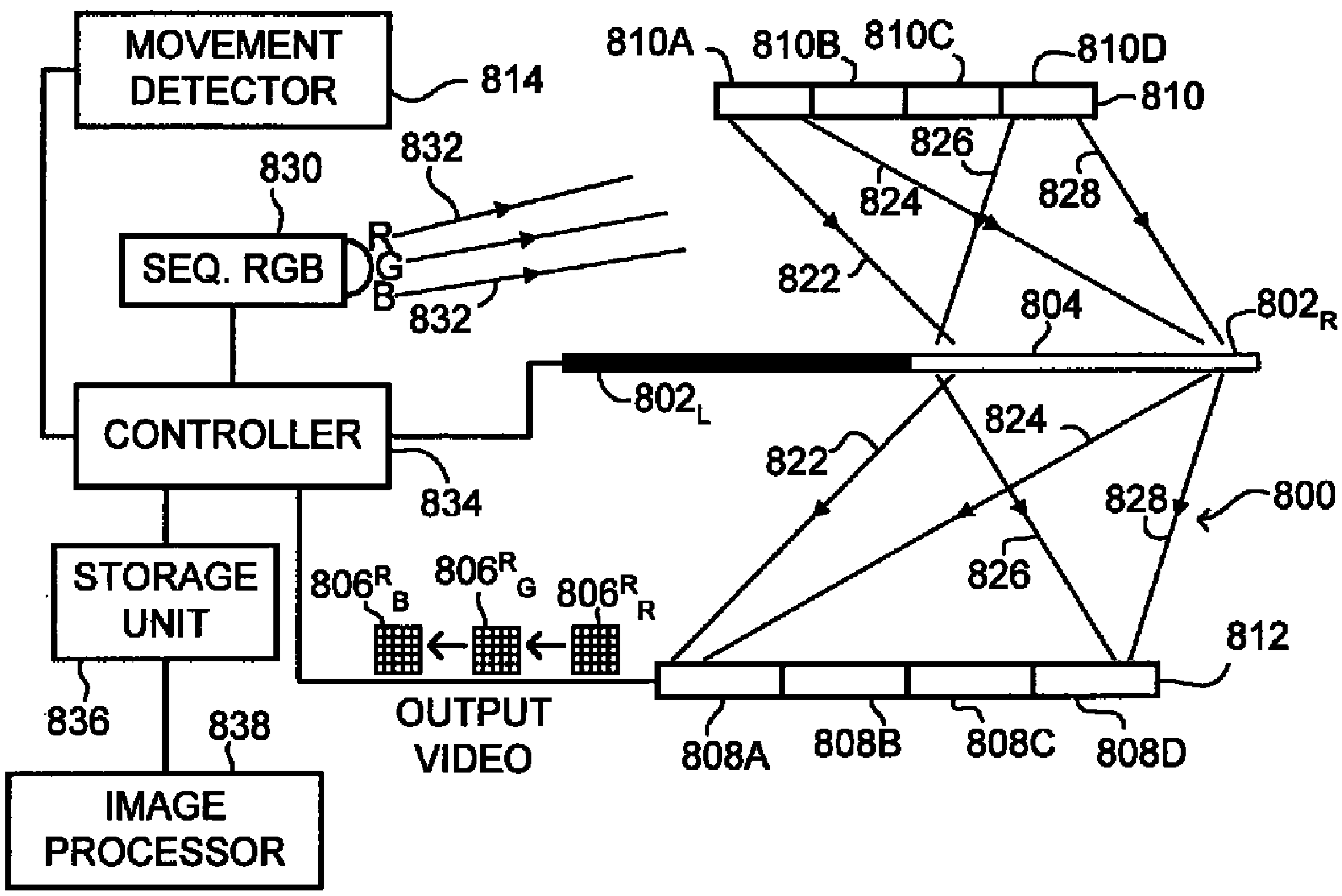


FIG. 20A

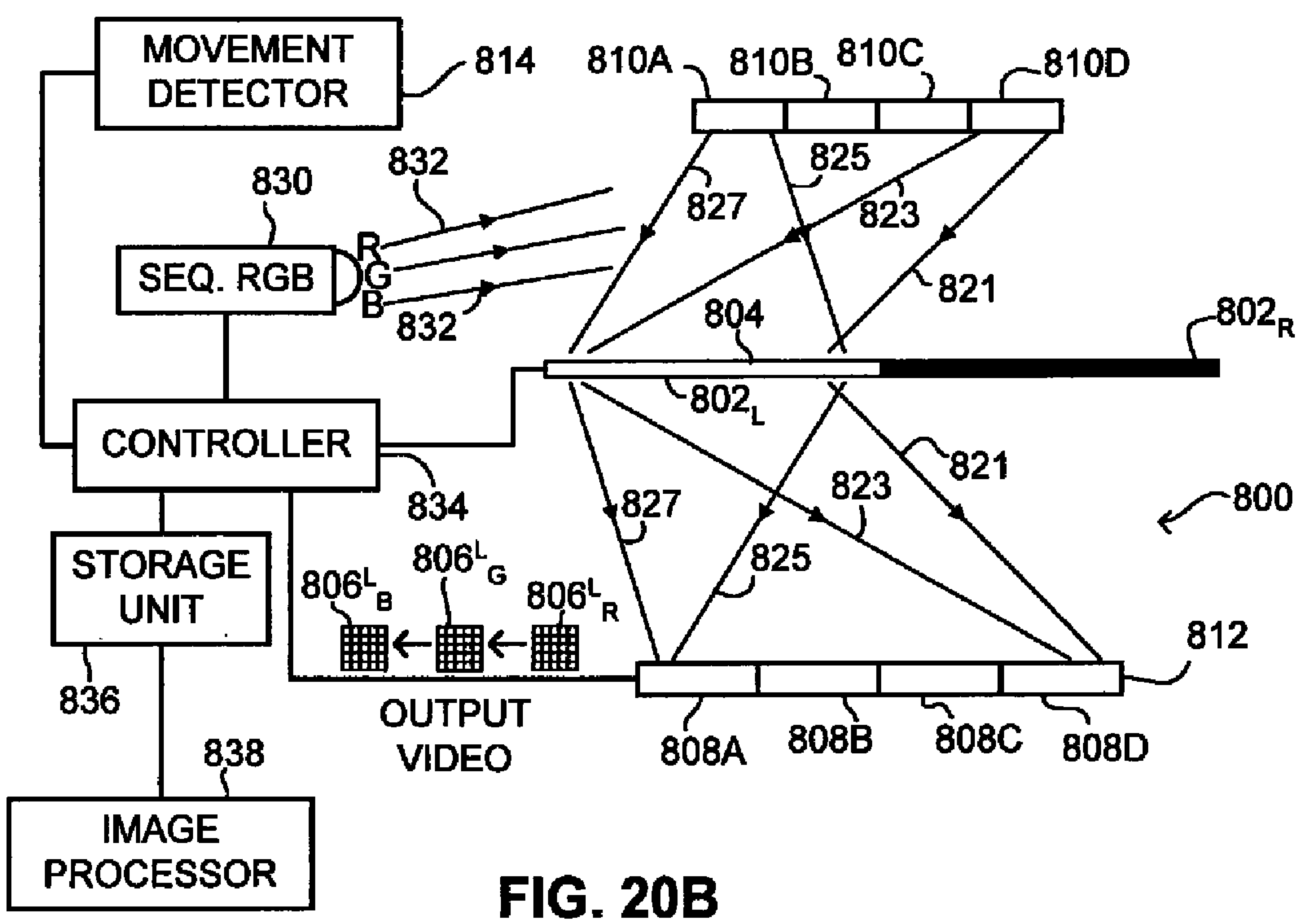


FIG. 20B

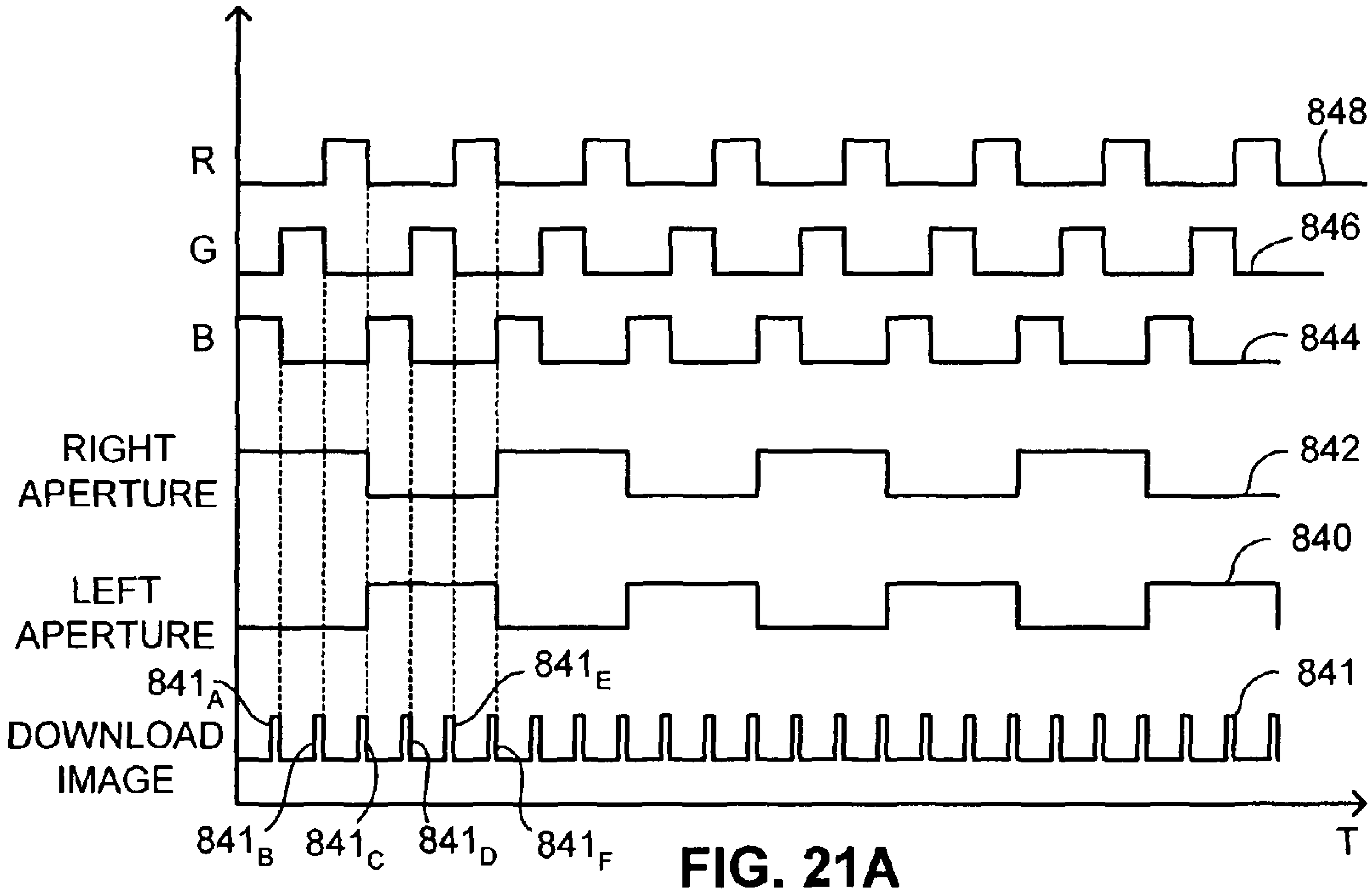


FIG. 21A

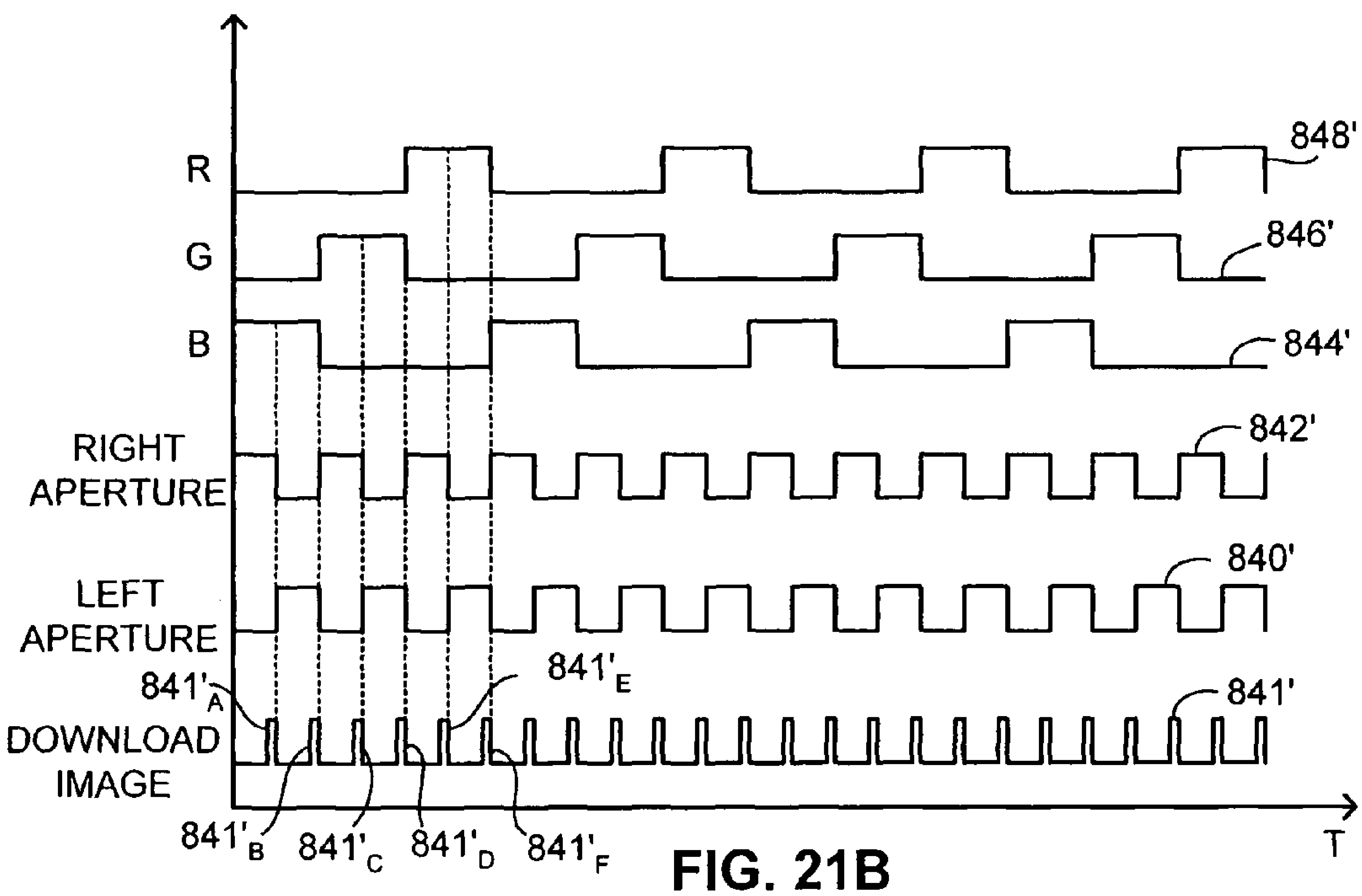


FIG. 21B

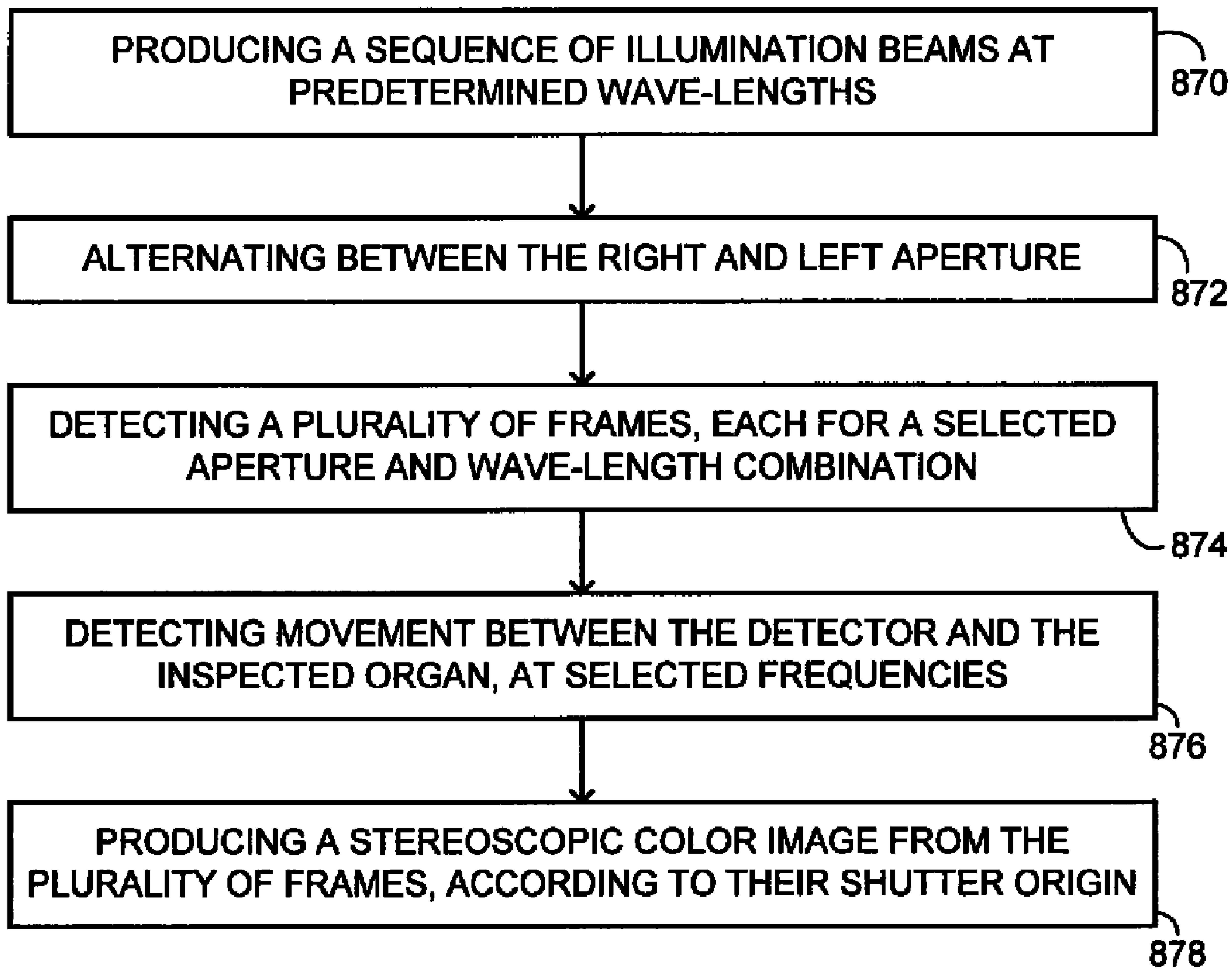

PRODUCING A SEQUENCE OF ILLUMINATION BEAMS AT PREDETERMINED WAVE-LENGTHS
870
ALTERNATING BETWEEN THE RIGHT AND LEFT APERTURE
872
DETECTING A PLURALITY OF FRAMES, EACH FOR A SELECTED APERTURE AND WAVE-LENGTH COMBINATION
874
DETECTING MOVEMENT BETWEEN THE DETECTOR AND THE INSPECTED ORGAN, AT SELECTED FREQUENCIES
876
PRODUCING A STEREOSCOPIC COLOR IMAGE FROM THE PLURALITY OF FRAMES, ACCORDING TO THEIR SHUTTER ORIGIN
878

FIG. 22

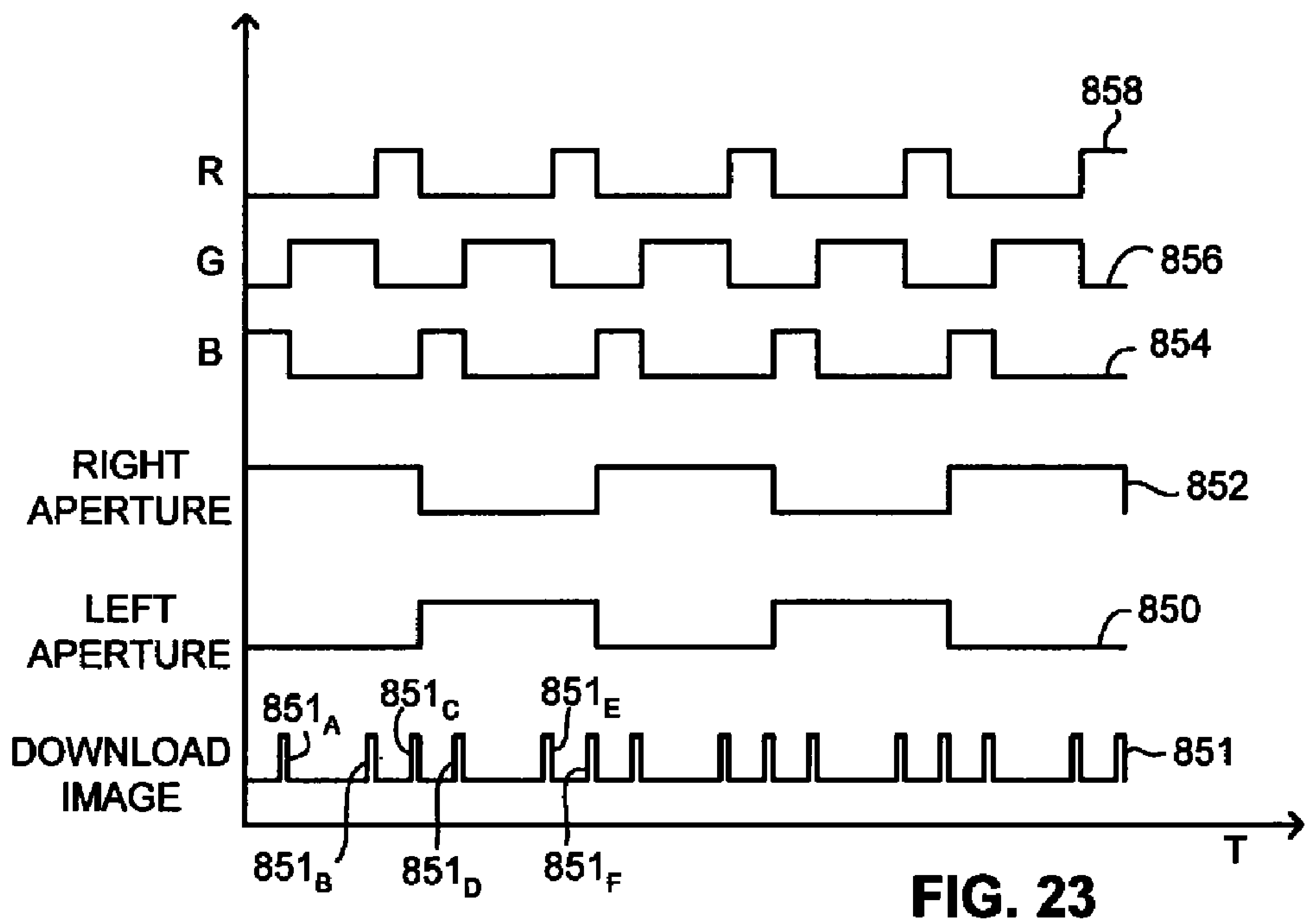

R
G
B
RIGHT APERTURE
LEFT APERTURE
DOWNLOAD IMAGE
858
856
854
852
850
851
851A
851B
851C
851D
851E
851F
T

FIG. 23

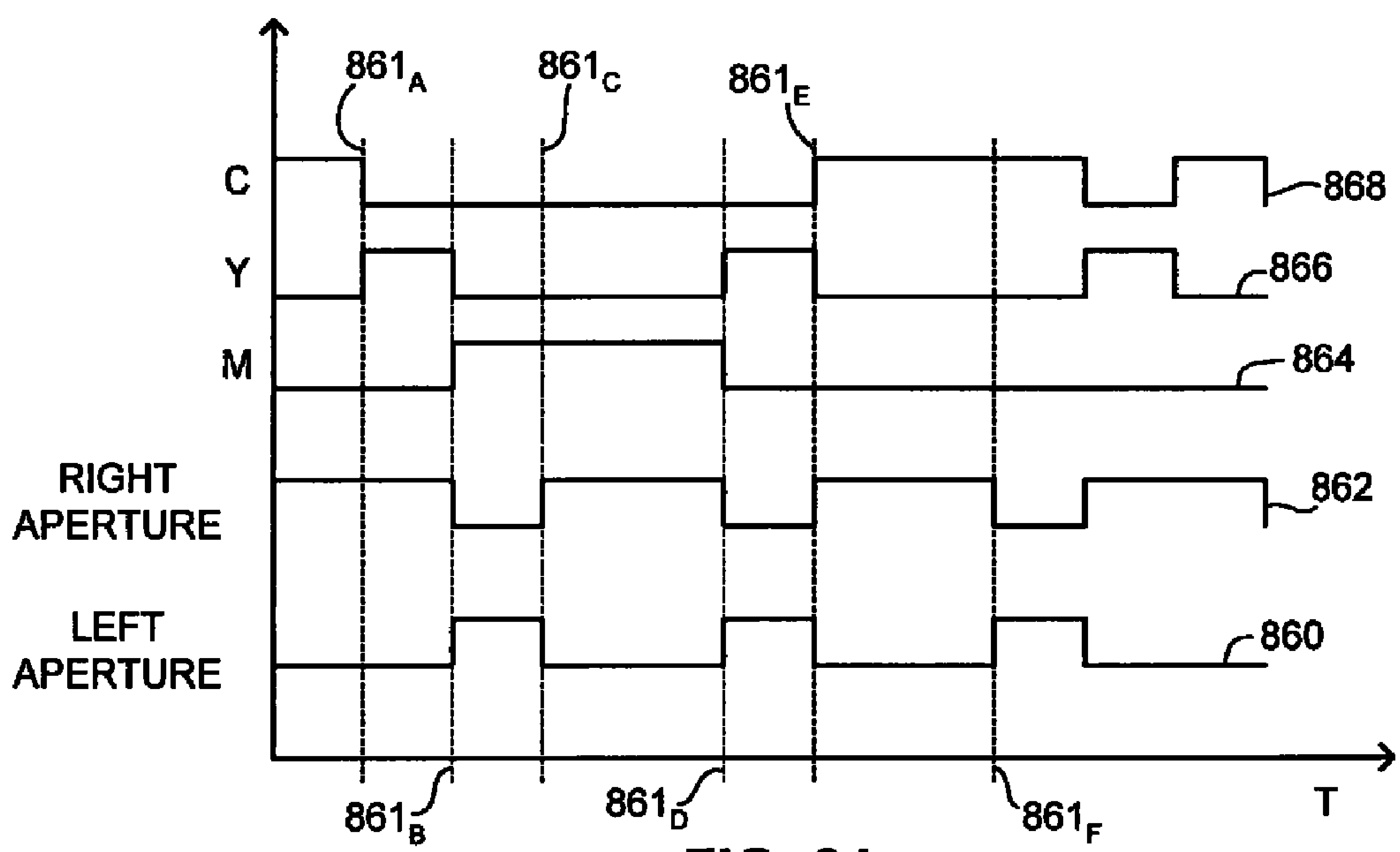

C
Y
M
RIGHT APERTURE
LEFT APERTURE
861A
861B
861C
861D
861E
861F
868
866
864
862
860
T

FIG. 24

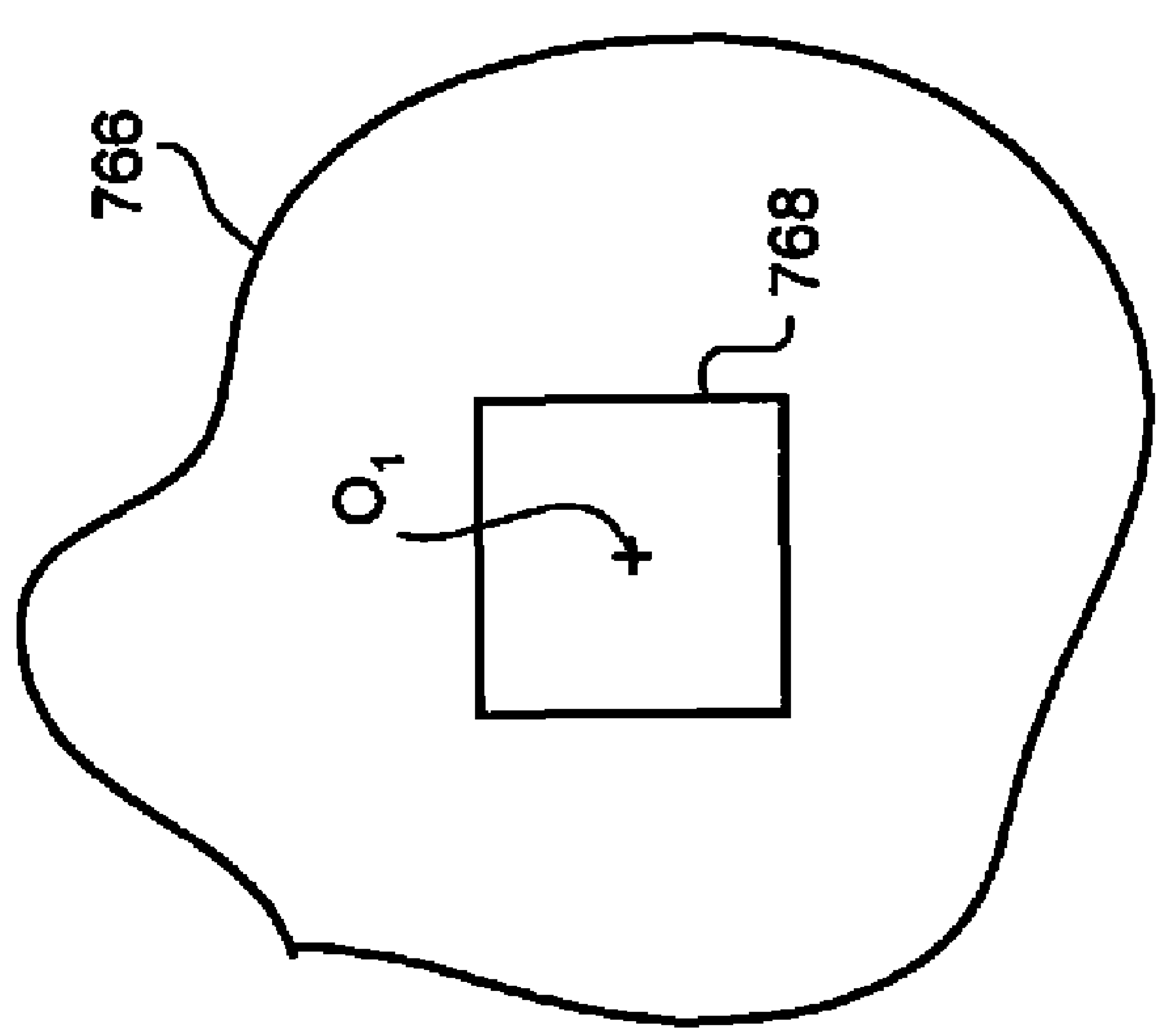


FIG. 25A

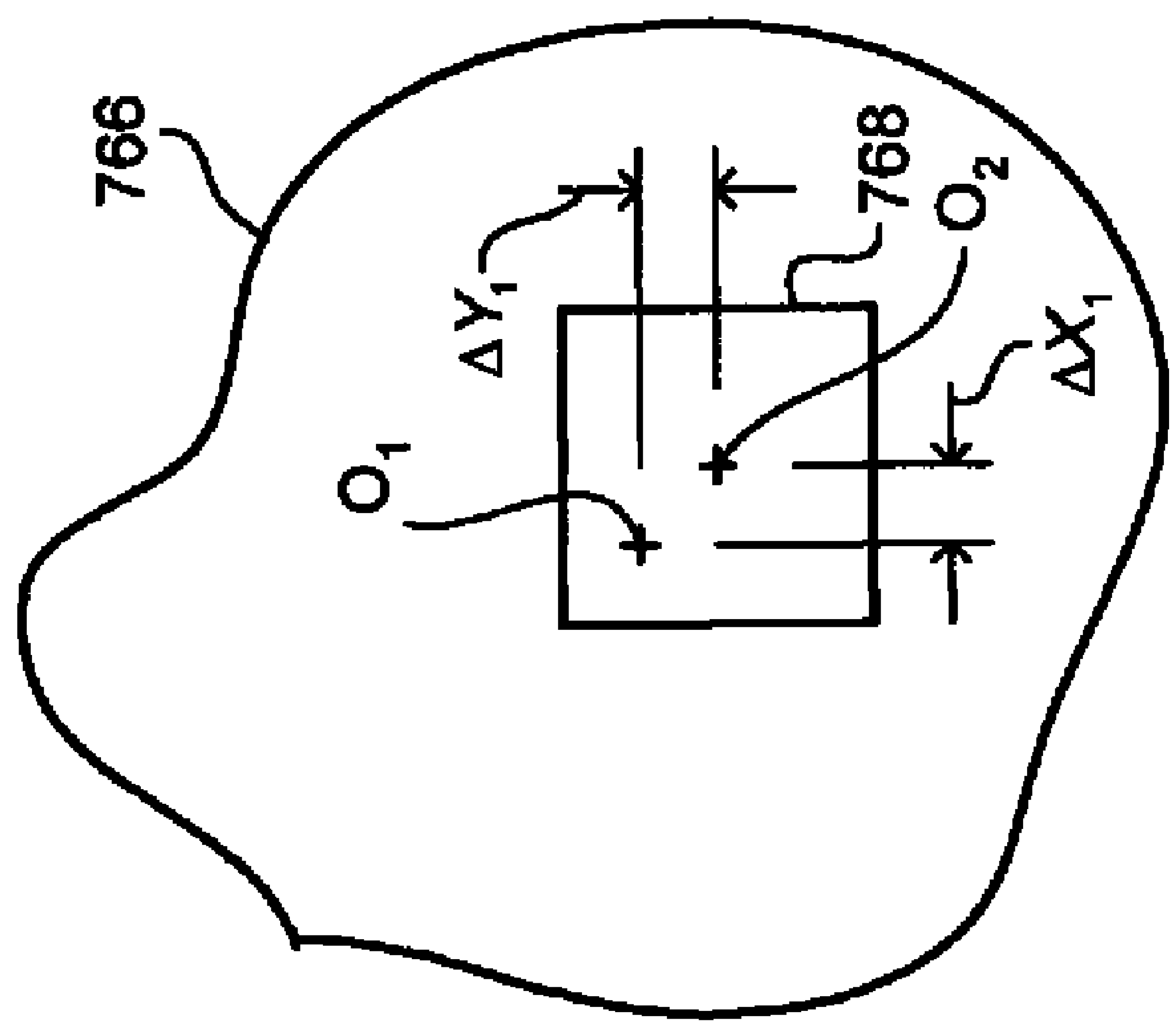


FIG. 25B

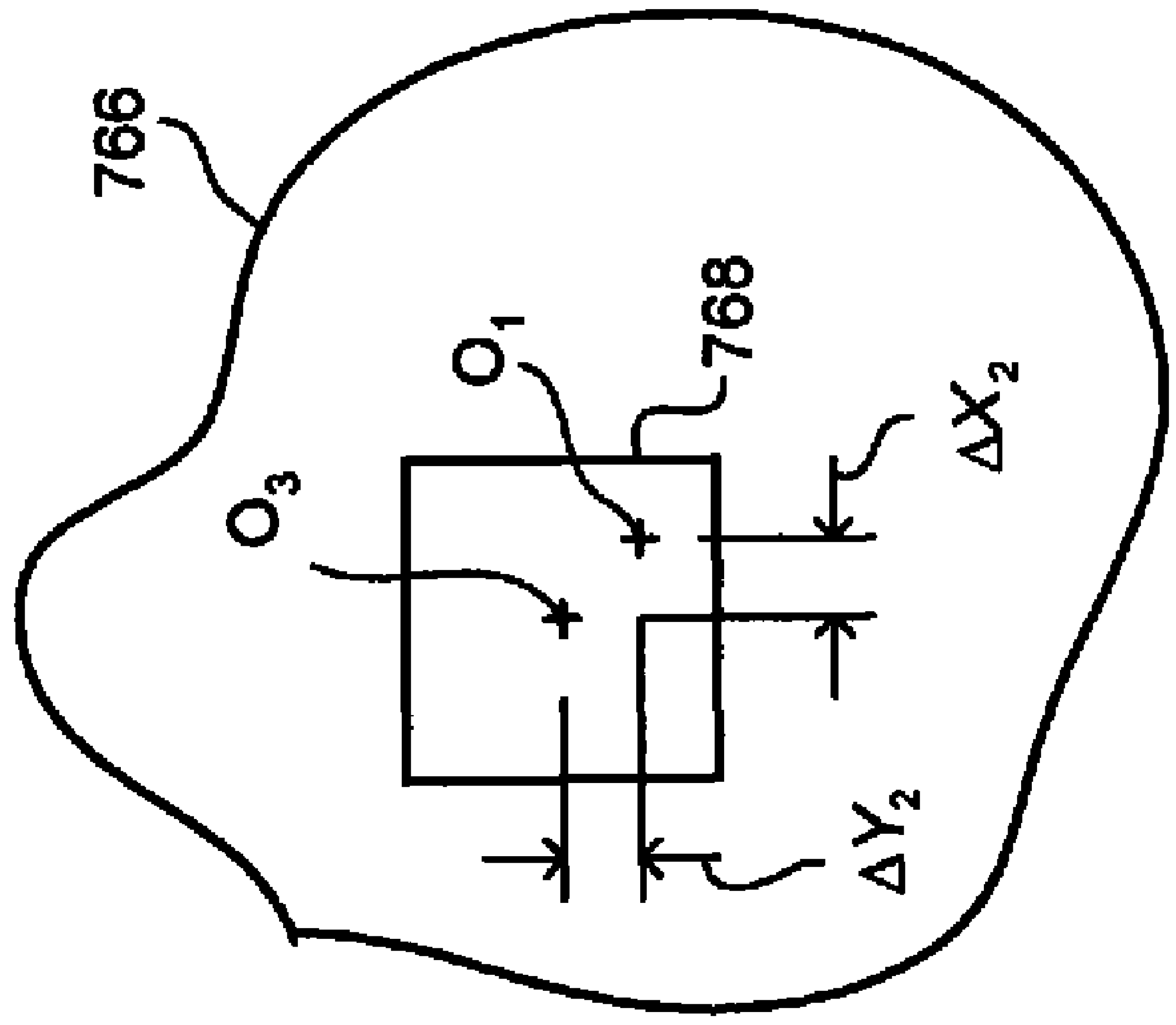


FIG. 25C

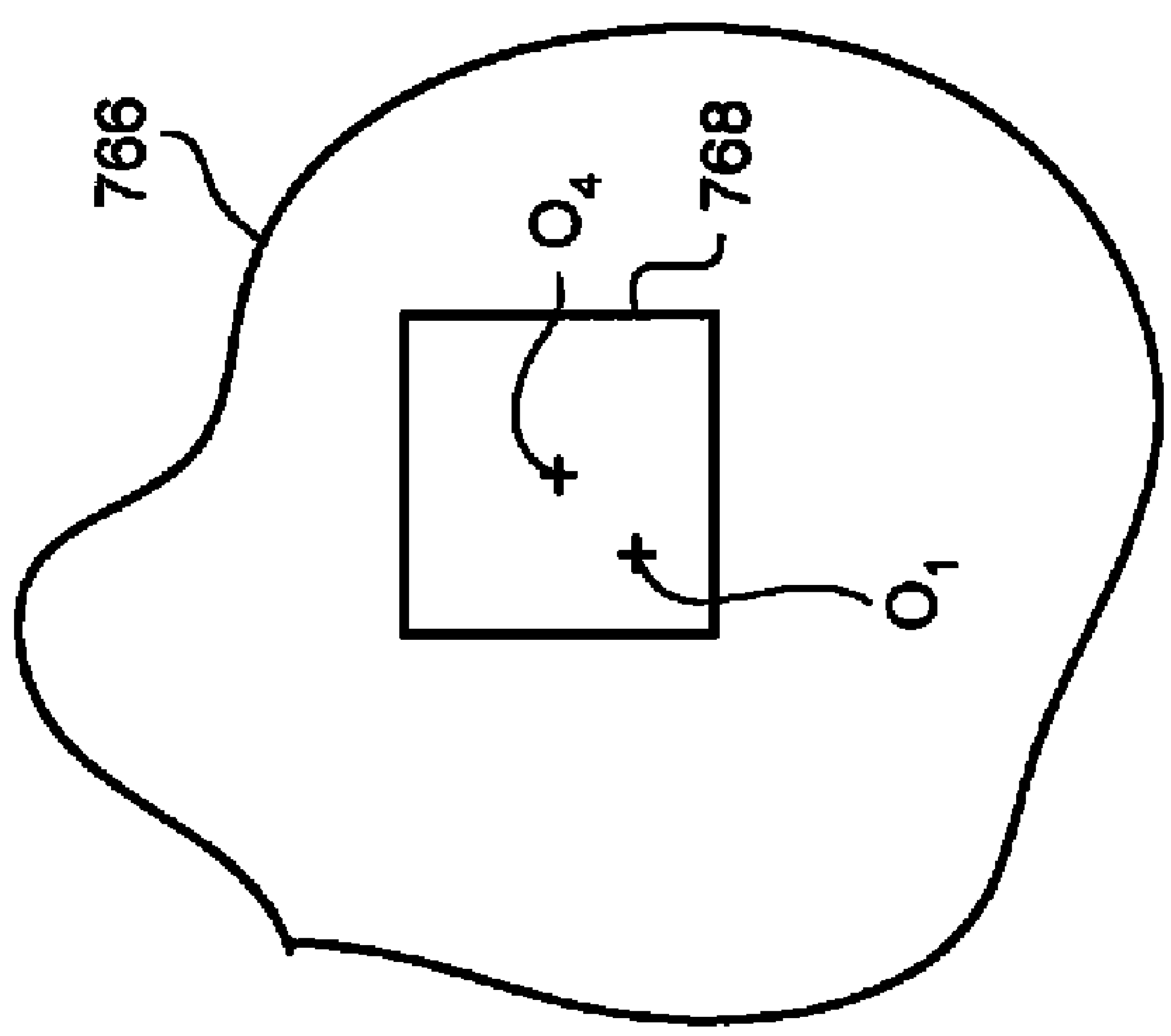


FIG. 25D

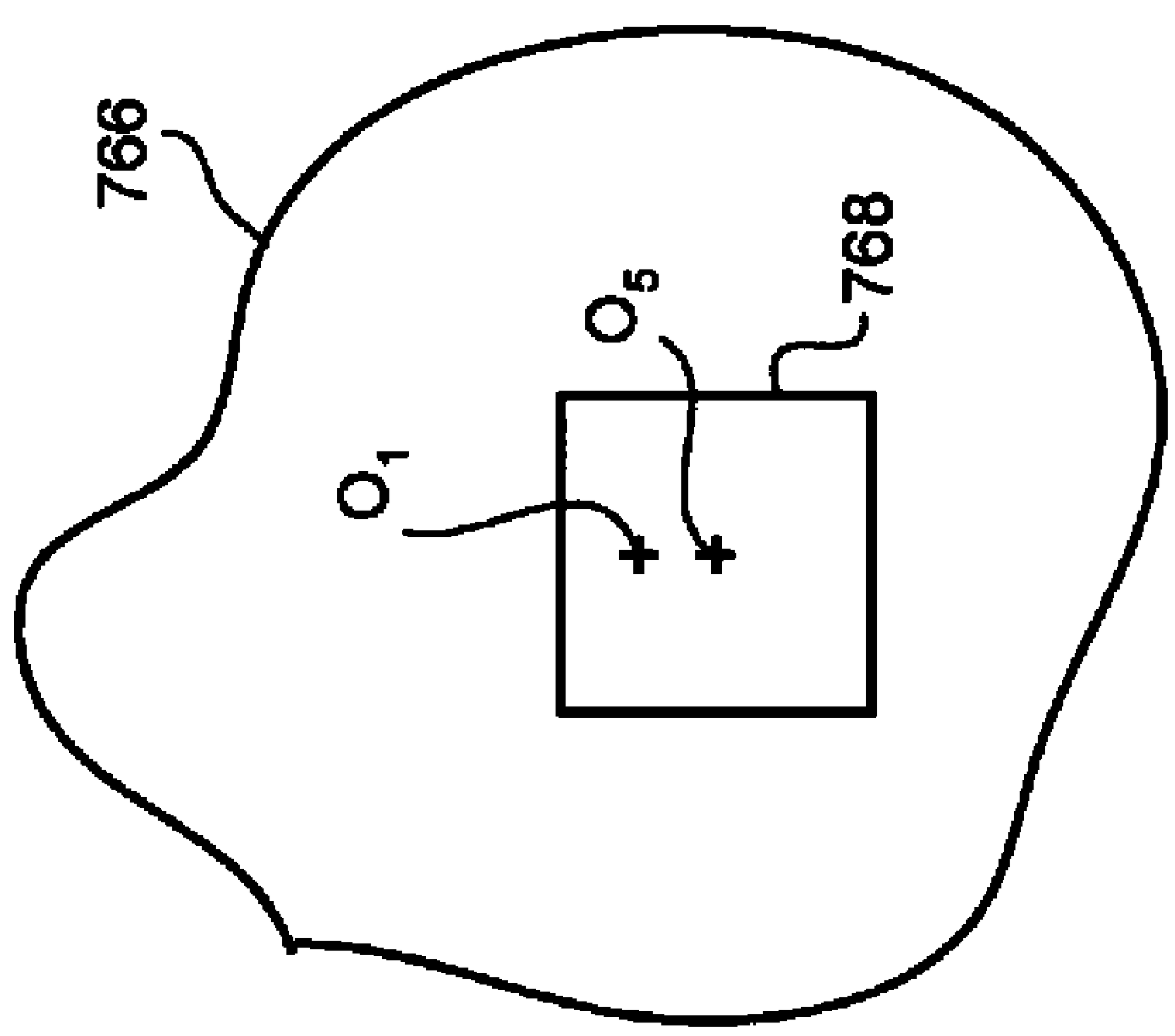


FIG. 25E

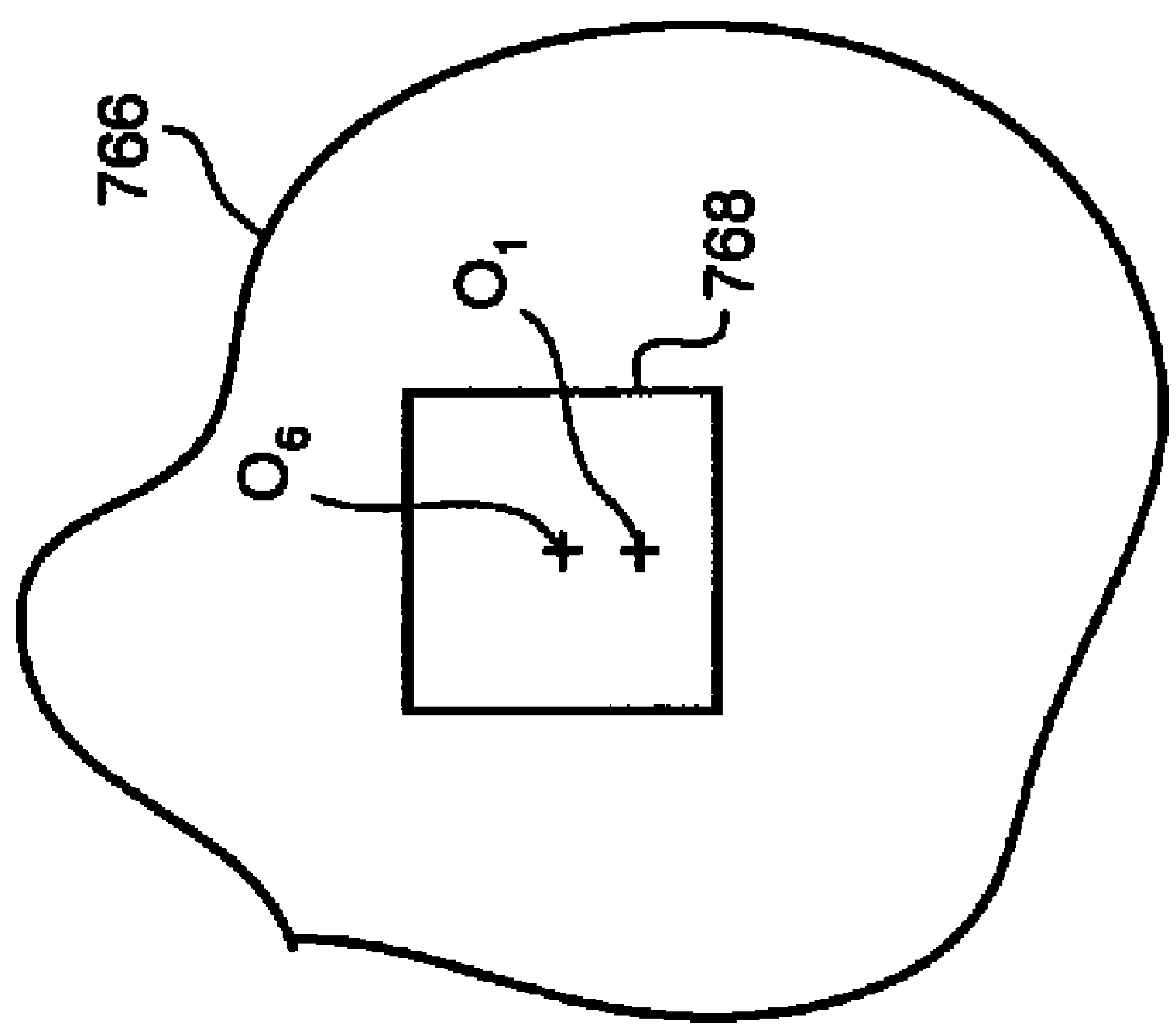


FIG. 25F

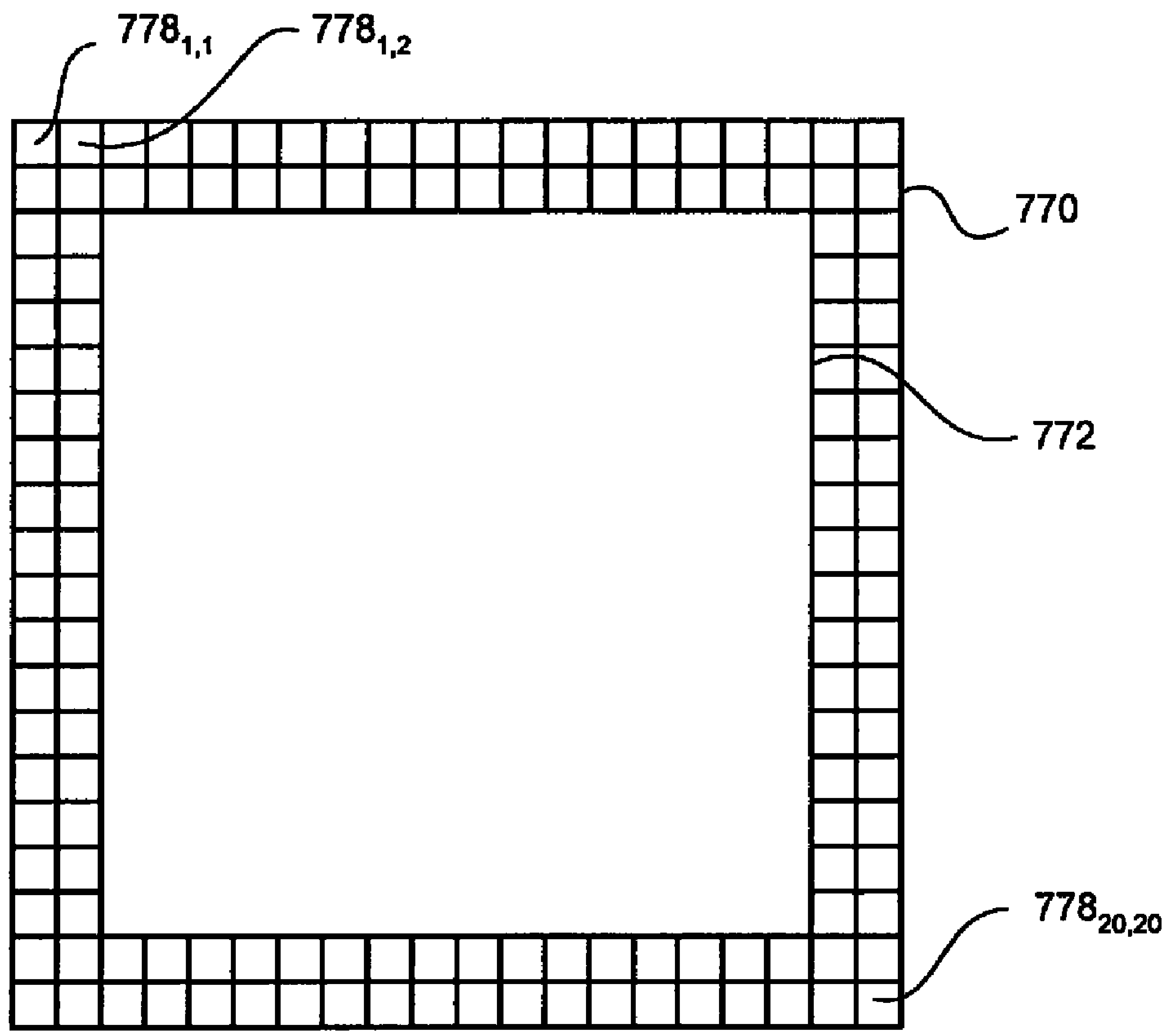


FIG. 26A

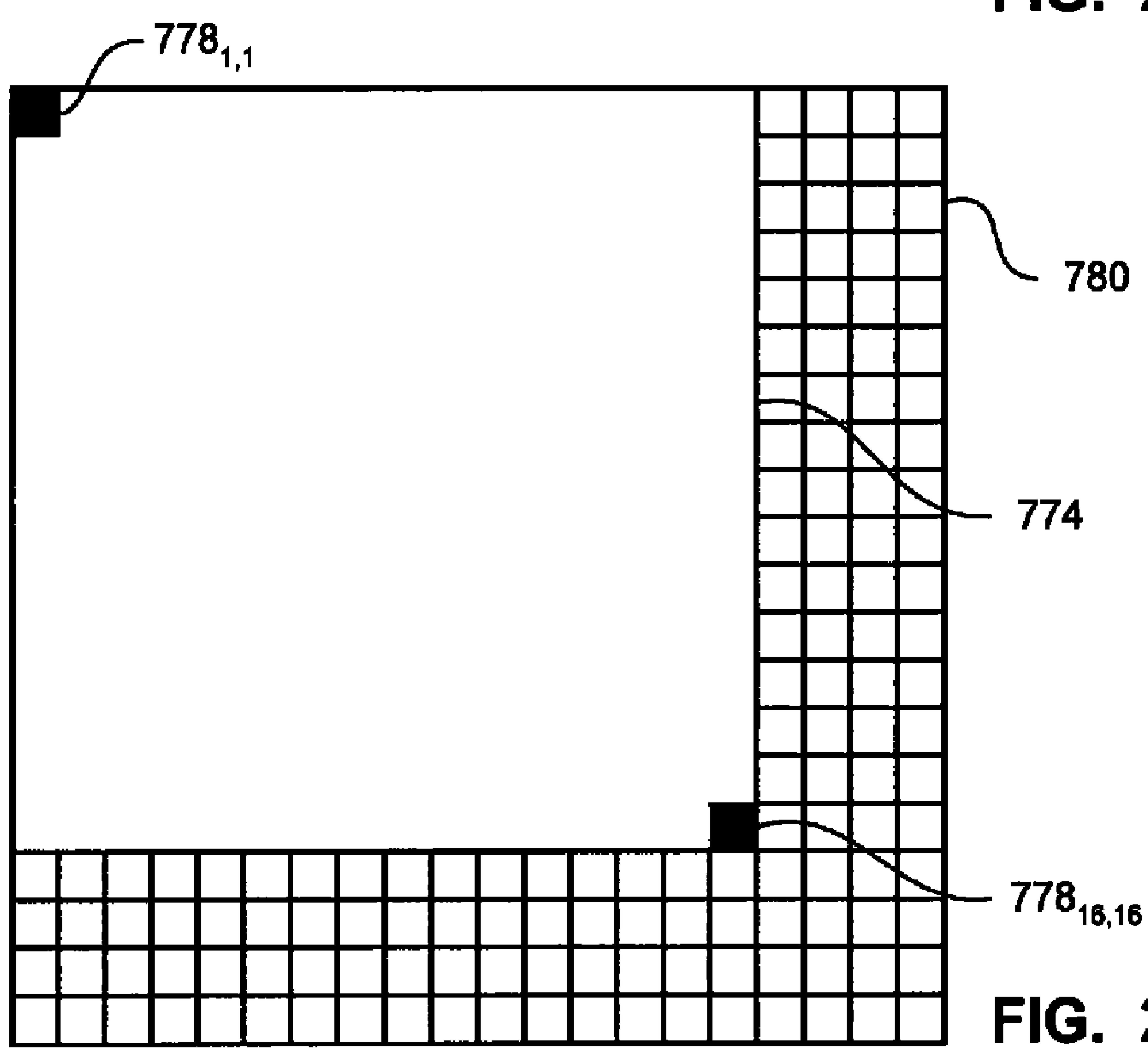


FIG. 26B

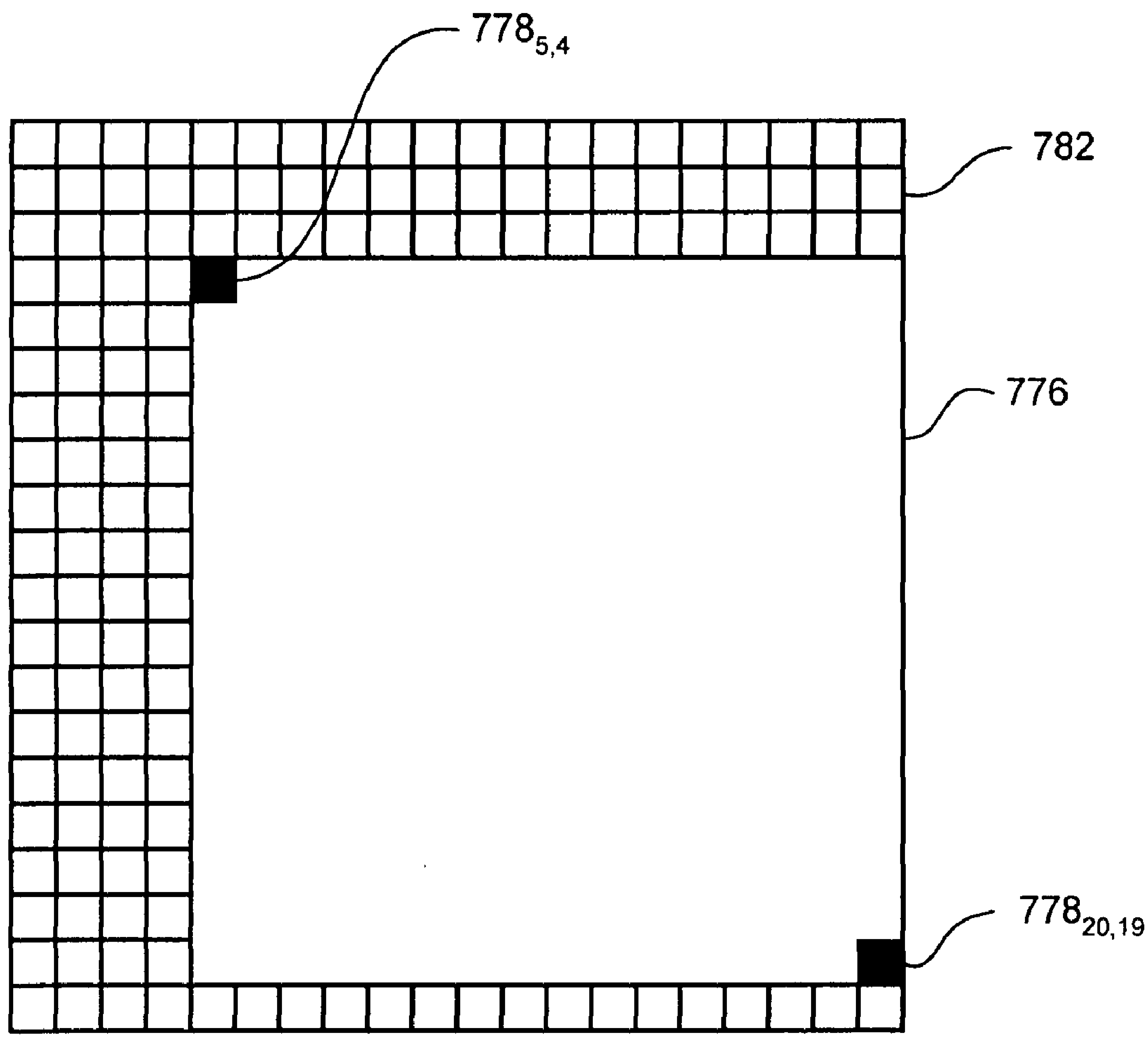
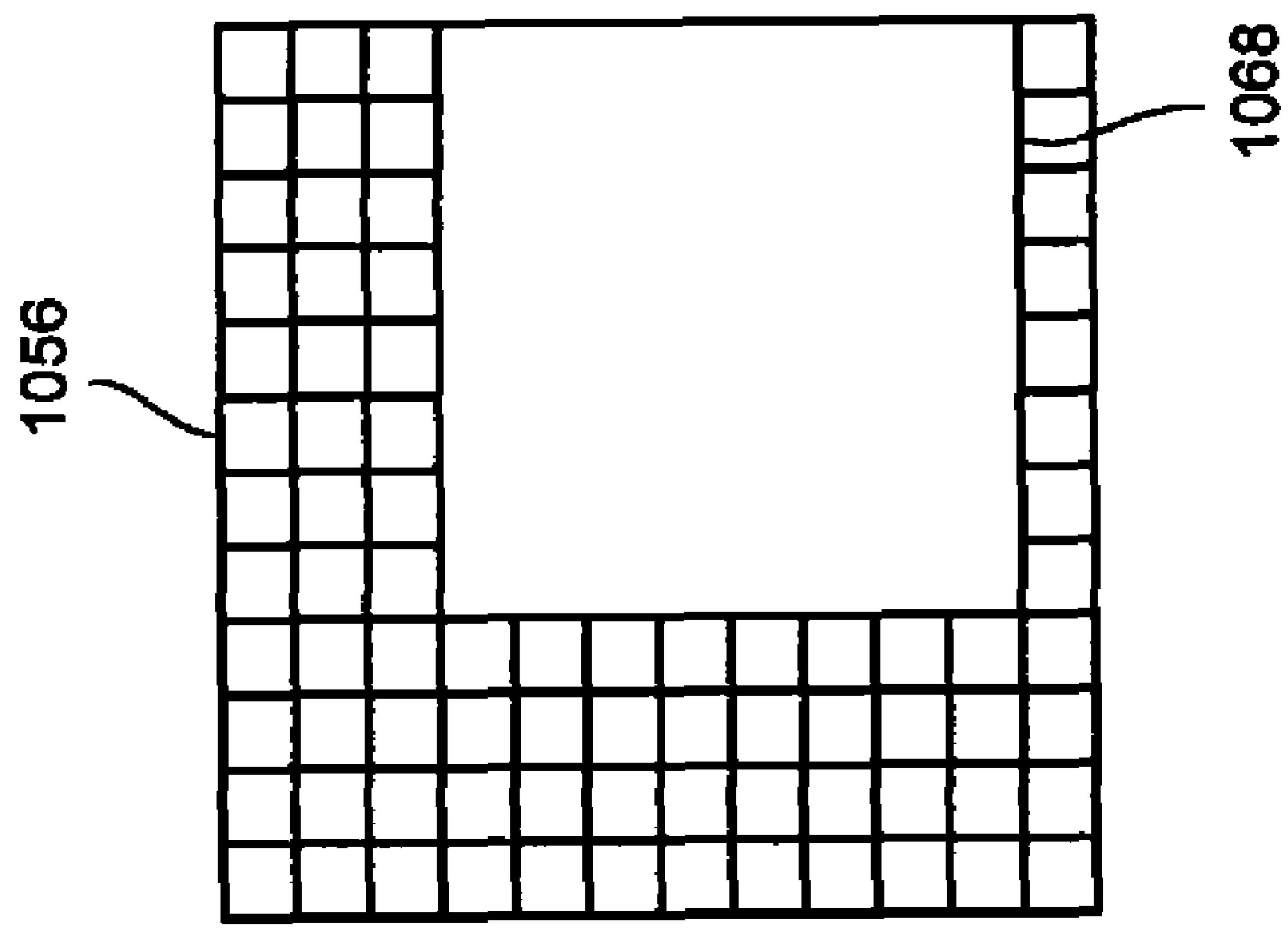
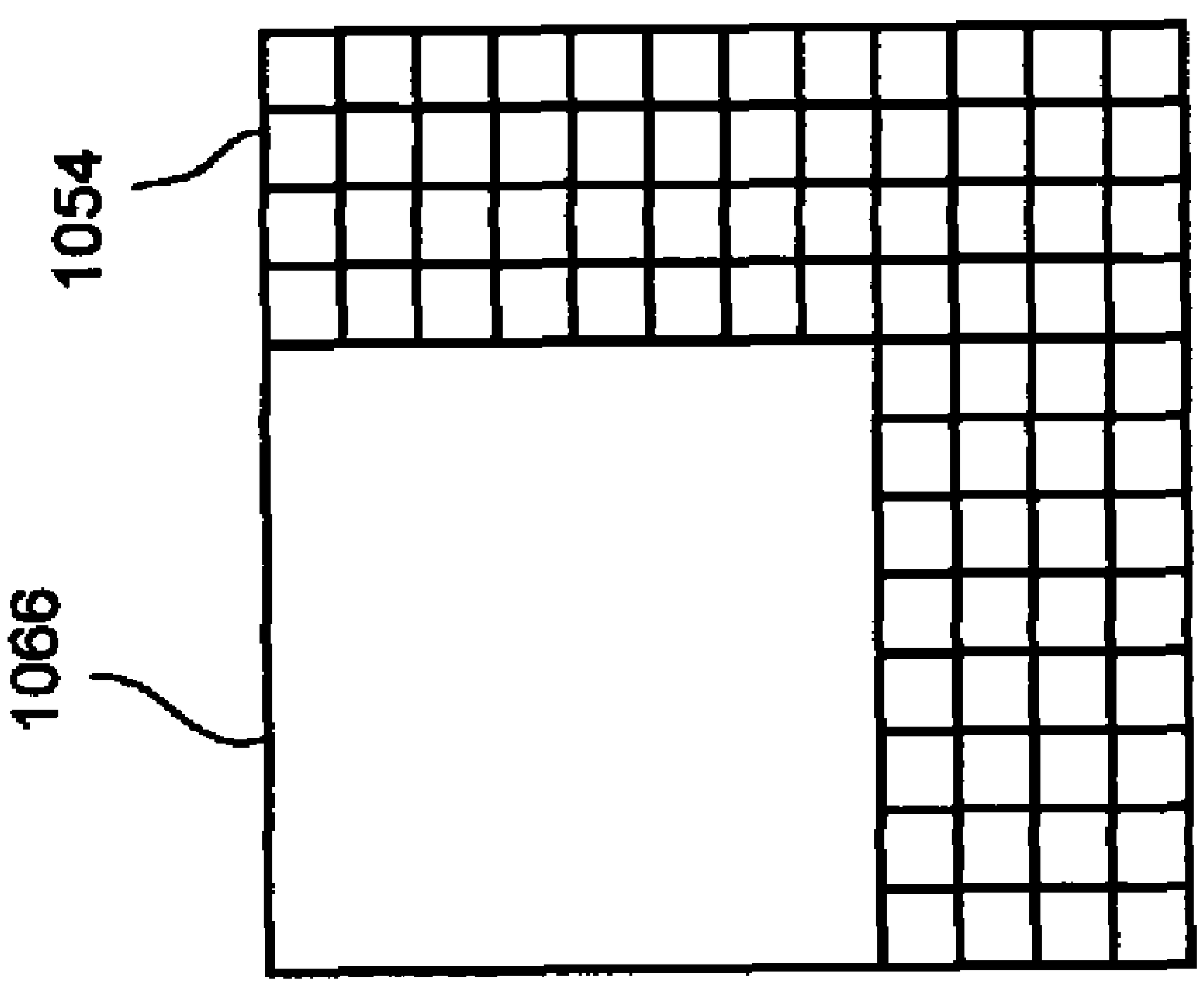


FIG. 26C



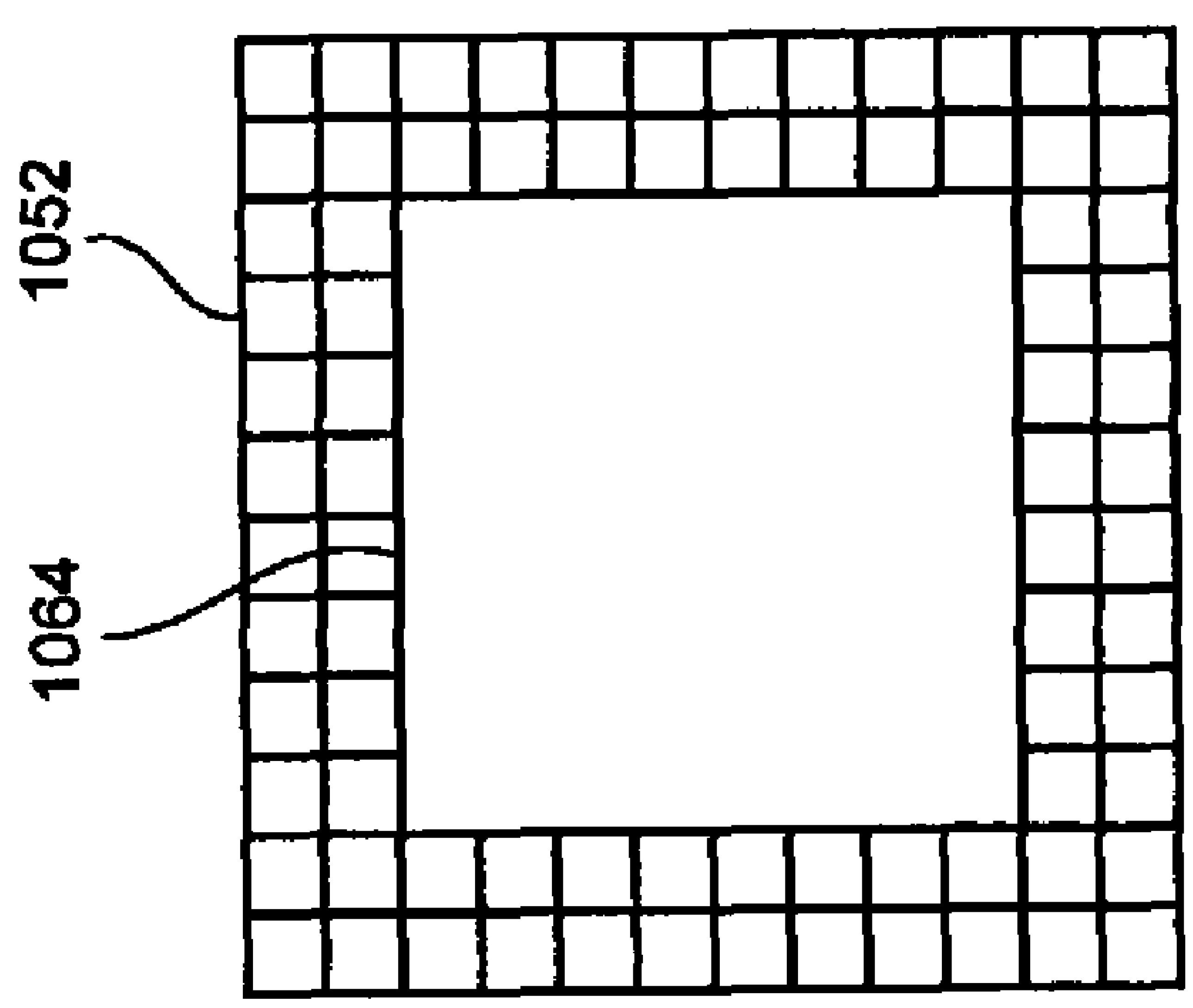
RIGHT (GREEN)

FIG. 27C



LEFT (BLUE)

FIG. 27B



RIGHT (BLUE)

FIG. 27A

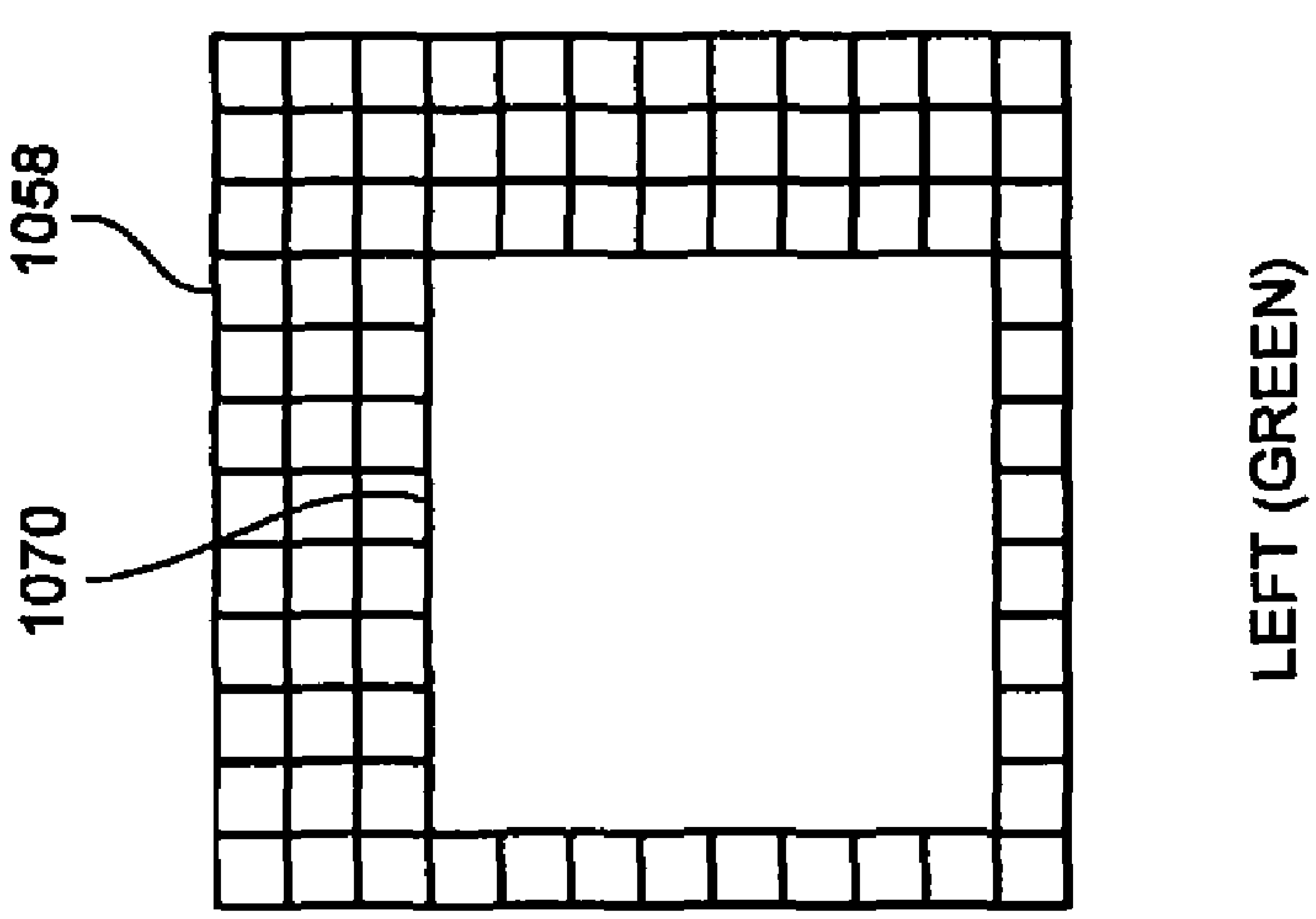


FIG. 27D

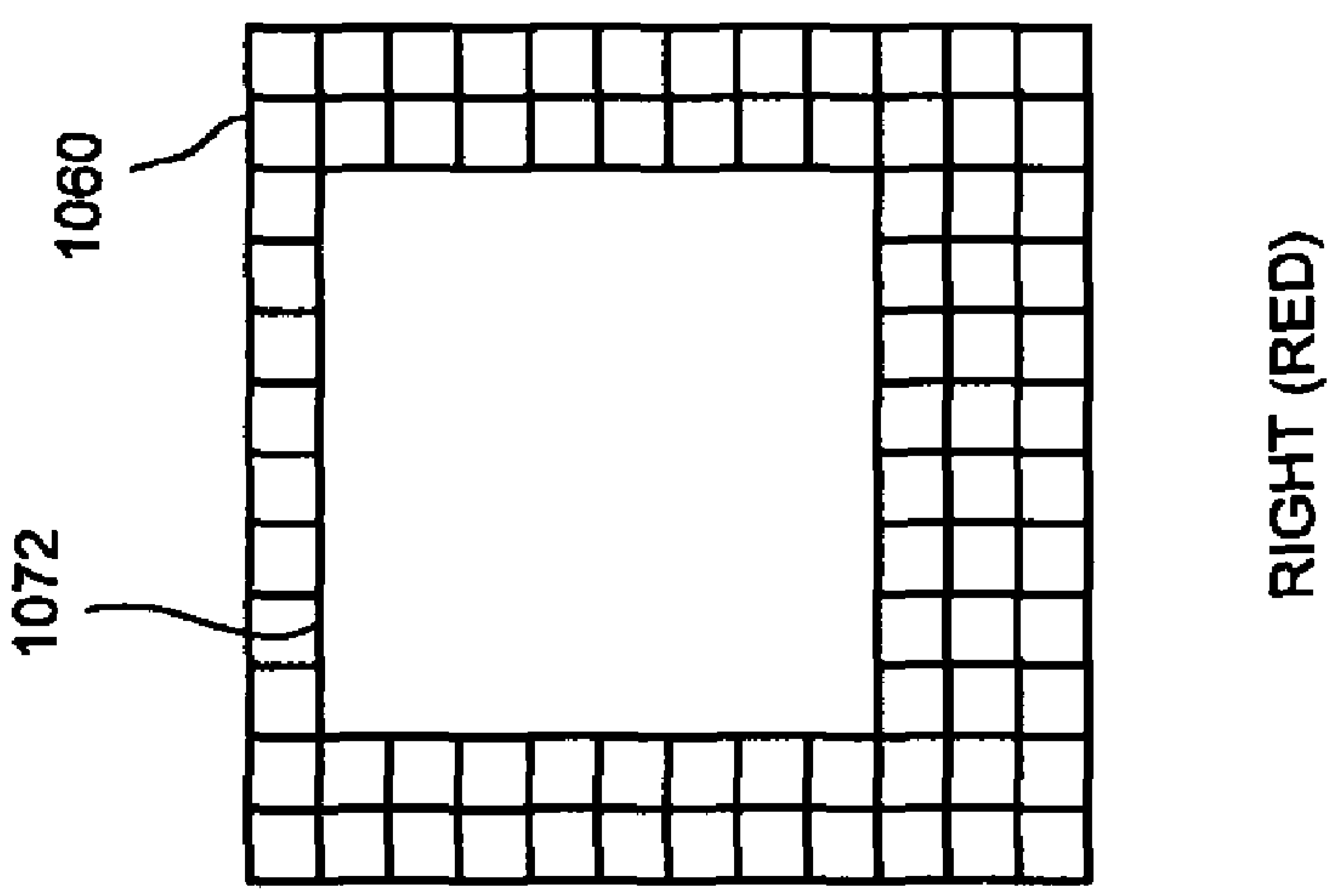


FIG. 27E

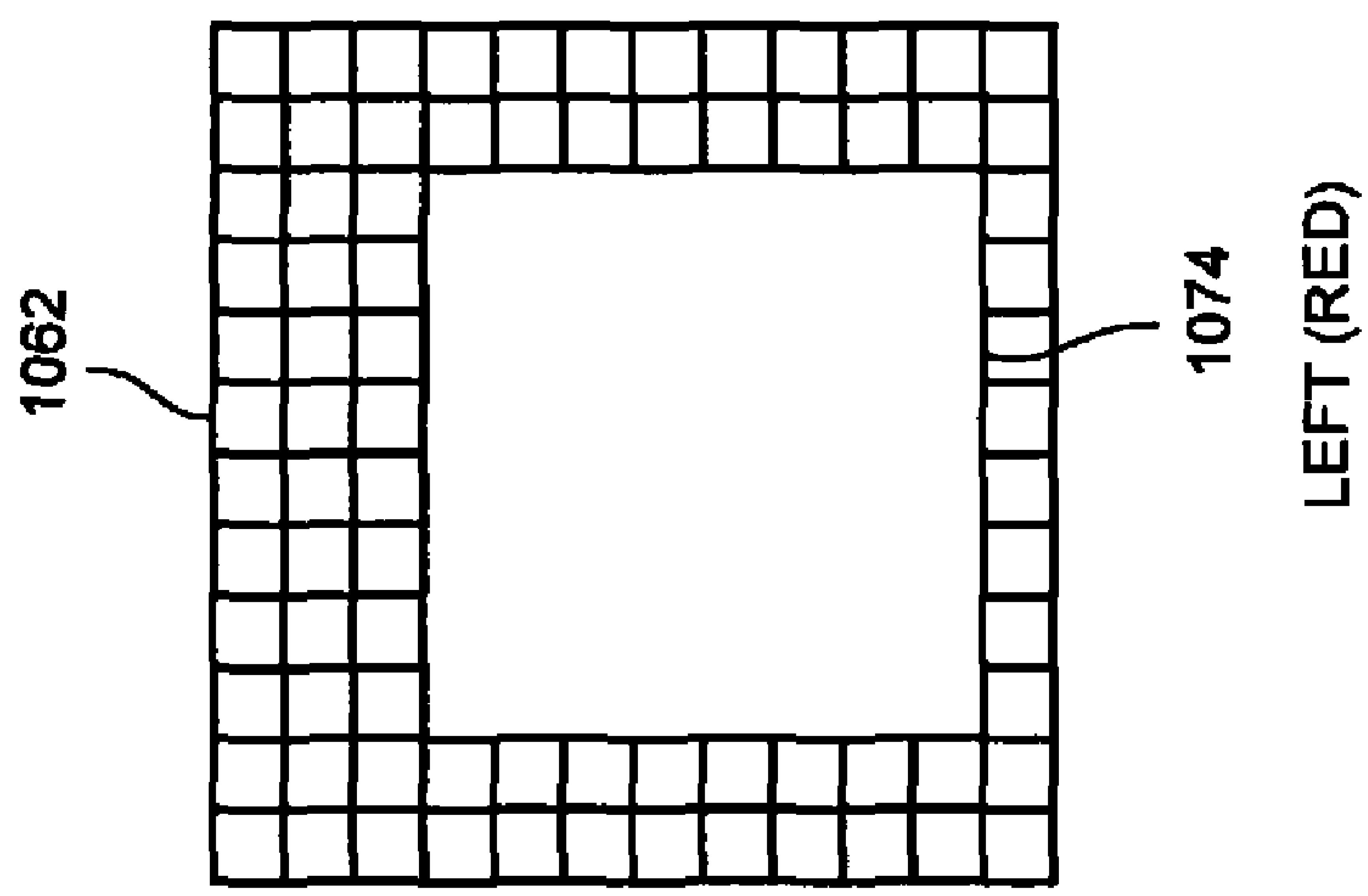


FIG. 27F

OPTICAL DEVICE

CROSS REFERENCE INFORMATION

This application is a Continuation-in-Part of application Ser. No. 09/257,850, filed Feb. 25, 1999 now U.S. Pat. No. 6,396,873 and 09/699,624 filed Oct. 30, 2000 now U.S. Pat. No. 7,154,527.

FIELD OF THE INVENTION

The present invention relates to endoscopes, microscopes and boroscopes, in general and to stereoscopic image pick up devices with color imaging capability, in particular.

BACKGROUND OF THE INVENTION

Stereoscopic image detection devices are known in the art. Such devices are required to obtain and provide a combination of small cross section and high image quality. It will be appreciated by those skilled in the art that high image quality, in general, is characterized by stereoscopic vision accuracy, color capabilities, high resolution and illumination requirements.

It is noted that conventional methods, which provide stereoscopic images, require a wider optical path than a monocular one. Such a widened optical path enlarges the cross-section required for the detection device considerably. Hence, the requirement for a small cross section is not maintained.

U.S. Pat. No. 5,527,263 to Zobel et al., is directed to a dual optical path stereo endoscope with simple optical adjustment. U.S. Pat. No. 5,776,049 to Takahashi, is directed to a "Stereo Endoscope Imaging Apparatus" and provides a device which utilizes a combination of two optical paths with two CCD units, capable of variable zoom.

Auto-stereoscopic devices, which utilize one optical system to provide a stereo effect, are also known in the art. Such a device is provided in U.S. Pat. No. 5,603,687 to Hori et al., which is directed to a device with two parallel optical axis and two CCD elements. Hori selected an asymmetrical approach, wherein one optical channel has a large aperture for light and details and the other optical channel provides a parallax image for stereoscopic imagery to the proximal CCD.

U.S. Pat. No. 5,613,936 to Czarnek et al., is directed to a stereoscopic endoscope device which utilizes light polarization and time multiplexing in order to transmit each different polarized image corresponding to left and right images multiplexed in time, through one optical channel that transfers images from the lateral side of the endoscope shaft. This endoscope has to be inserted deeper into the human cavity to receive a stereo image. It must also be used with a head mounted display device called "switched shutter glasses" that causes eye irritation. It is noted that according to Czarnek each image is received in 25% of original quality. As much as 50% of the light received fro the object, is lost due to polarization considerations and as much as 50% of the remaining information is lost due to channel switching.

U.S. Pat. No. 5,588,948, to Takahashi et al., is directed to a Stereoscopic Endoscope. The stereo effect is produced by having a dividing pupil shutter, which splits the optical path onto the left and right sides, and the up and down sides. These sides are alternatively projected on a proximal image pickup device, using time multiplexing. According to another aspect of this reference includes a distal CCD, which is divided to left and right sides with a shading member separating them, for achieving space multiplexing.

U.S. Pat. No. 5,743,847 to Nakamura et al., is directed to a "Stereoscopic Endoscope Having Image Transmitting Optical-System and Pupil Dividing Unit that are Axially Movable With Respect to Each Other", which uses a plural pupil dividing means and one optical channel. U.S. Pat. No. 5,751,341 to Chaleki et al., is directed to a "Stereoscopic Endoscope System", which is basically a two channel endoscope, with one or two proximal image sensors. A rigid sheath with an angled distal tip could be attached to its edge and be rotated, for full view.

U.S. Pat. No. 5,800,341 to Mckenna et al, who is directed to an "Electronically Steerable Endoscope", which provides different fields of view, without having to move the endoscope, using a plurality of CCD cells and processing means. U.S. Pat. No. 5,825,534 to Strahle, is directed to a "Stereo Endoscope having a Folded Sight Line" including stereo-endoscope optical channel, having a sight line folded relative to tube axis.

U.S. Pat. No. 5,828,487 to Greening et al., is directed to a "Stereoscopic Viewing System Using a Two Dimensional Lens System" which in general, provides an alternative R-L switching system. This system uses a laterally moving opaque leaf, between the endoscope and the camera, thus using one imaging system. U.S. Pat. No. 5,594,497 to Ahern, describes a distal color CCD, for monocular view in an elongated tube.

The above descriptions provide examples of auto-stereoscopic inventions, using different switching techniques (Time division multiplexing) and polarization of channels or pupil divisions (spatial multiplexing), all in an elongated shaft. When color image pick up devices are used within these systems, the system suffers from reduced resolution, loss of time related information or a widened cross section.

The issue of color imagery or the issue of a shaft-less endoscope is not embedded into any solution. To offer higher flexibility and to reduce mechanical and optical constraints it is desired to advance the image pick-up device to the frontal part of the endoscope. This allows much higher articulation and lends itself easily to a flexible endoscope. Having a frontal pick up device compromises the resolution of the color device due to size constraints (at this time).

U.S. Pat. No. 5,076,687 to Adelson, is directed to an "Optical Ranging Apparatus" which is, in general a depth measuring device utilizing a lenticular lens and a cluster of pixels.

U.S. Pat. No. 5,760,827 to Faris, is directed to "Pixel Data Processing System and Method for Producing Spectrally-Multiplexed Images of Three-Dimensional Imagery for Use in Stereoscopic Viewing Thereof" and demonstrates the use of multiplexing in color and as such, offers a solution for having a color stereo imagery with one sensor. Nevertheless, such a system requires several sequential passes to be acquired from the object, for creating a stereo color image.

U.S. Pat. No. 5,812,187 to Watanabe, is directed to an Electronic Endoscope Apparatus. This device provides a multi-color image using a monochromatic detector and a mechanical multi-wavelength-illuminating device. The monochromatic detector detects an image, each time the multi-wavelength-illuminating device produces light at a different wavelength.

SUMMARY OF THE PRESENT INVENTION

It is an object of the present invention to provide a novel system for stereoscopic imaging using a lenticular lens layer and a sensor array, and a novel method for operating the same, which overcomes the disadvantages of the prior art.

In accordance with the present invention, there is thus provided a stereoscopic device, which includes a lenticular lens layer and a color light sensor array. The lenticular lens layer includes a plurality of lenticular elements. Each of the lenticular elements is located in front of a selected group of the light sensors of the sensor array, thereby directing light from different directions to different light sensors within the selected group of the light sensors.

In accordance with a further aspect of the invention, there is provided a stereoscopic device, which includes a lenticular lens layer and a light sensor array, including a plurality of light sensors, where each of the light sensors detects light at a predetermined range of wavelengths.

The stereoscopic device according to the invention can be constructed as a large-scale device, such as a television camera or a small-scale device such as an endoscope.

In a stereoscopic device according to the invention, each of the lenticular elements includes light directing means, which distinguish between at least two directions of light. For example, each of the lenticular elements can be shaped in a general semi-cylindrical shape. Each of the lenticular elements can alternatively include light directing means, which distinguish between four directions of light. For example, such a lenticular element can be shaped in a general semi-spherical shape.

According to one aspect of the invention, each of the selected groups of the light sensors includes an even number of light sensors. According to another aspect of the invention, each of the selected groups of the light sensors includes an odd number of light sensors.

The stereoscopic device of the invention can further include an illuminating unit. This light illuminating unit can surround the lenticular lens layer. An illumination unit according to the invention includes a light source, a light distribution unit and light guiding means connected between the light source and the light dispersing unit. The light guiding means guides light from the light source to the light dispersing unit. According to one aspect of the invention, the light dispersing unit surrounds the lenticular lens layer.

The light illuminating unit can produce light in a predetermined range of wavelengths. According to another aspect of the invention, the light illuminating unit produces at least two alternating beams of light, where each of the beams of light is characterized as being in a different range of wavelengths.

The stereoscopic device according to the invention, can further include a controller connected to the array of light sensors. This controller produces an image for each of the different directions, by combining data received from the light sensors respective of each of the different directions.

This controller can be connected to the array of light sensors. Accordingly, the controller produces an image for each combination of a selected one of the different directions and a selected one of the beams of light, by combining data received from the light sensors respective of each of the different directions, with respect to the currently illuminating one of the beams of light.

The stereoscopic device according to the invention can further include capturing means, connected to the array of light sensors, for capturing data received from light sensors and a storage unit for storing the captured data. The stereoscopic device can further include a stereoscopic display unit, connected to the controller, for producing the image in a stereoscopic manner. The produced image can be partially stereoscopic.

The predetermined ranges of wavelengths, which are applicable for the light sensors as well as for the illumination light beams can be substantially visible red color light, substantially visible green color light, substantially visible blue color light, substantially visible cyan color light, substantially visible yellow color light, substantially visible magenta color light, substantially infra-red light, substantially ultra-violet light, visible light, and the like.

For example, either the light sensor array or the light beams can include a color combination of red-green-blue (RGB), cyan-yellow-magenta-green (CYMG), a white light color combination, and the like.

In accordance with a further aspect of the invention, there is thus provided a method for detecting a stereoscopic image. The method includes the steps of splitting light which arrives from different directions, using a lenticular lens layer, thereby producing at least two images, which are intertwined in a master image, and detecting the master image.

The method can further include the step of reconstructing each of the images from the master image. In addition, the method can further include the step of displaying the images using a stereoscopic display device.

Furthermore, the method can include the step of simultaneously displaying the images on a stereoscopic display device. In addition, the method can further include the steps of sequentially illuminating a detected area with alternating beams of light of different ranges of wavelength, and associating the master image in time, with the currently illuminating ranges of wavelength.

The step of reconstructing can include the steps of determining a range of wavelengths for each pixel within each one of the images, and determining an intensity level for each pixel within each one of the images. The step of reconstructing can further include the steps of selecting one of the pixels, associated with a predetermined range of wavelengths and determining the pixels associated with another range of wavelengths, in the vicinity of the selected pixel. The step of reconstructing can further include the steps of calculating an approximated level of the other range of wavelengths at the location of the selected pixel and starting again from the step of selecting.

In accordance with another aspect of the present invention, there is thus provided a stereoscopic device for detecting a stereoscopic image. The stereoscopic device includes at least two apertures, a multi wavelength light sensor array and a controllable multi wavelength illumination unit. Each aperture includes a plurality of light valves. The controllable multi wavelength illumination unit produces at least two alternating beams of tight, where each beam of light is characterized as being in a different range of wavelengths. Each light valve is operative to open at a different predetermined timing. Furthermore, the multi wavelength light sensor array detects a plurality of images, where each of the images corresponds to a predetermined combination of an open state of a selected light valve and a selected mode.

In accordance with a further aspect of the present invention, there is thus provided a method for detecting a stereoscopic image. The method includes the steps of alternating between at least two apertures, producing a sequence of at least two illumination beams and detecting a plurality of frames. The apertures are directed at an object. The illumination beams are produced in different ranges of wavelengths. Each of the frames is detected for a combination, which includes a selected aperture and a selected illumination beam.

In accordance with another aspect of the present invention, there is thus provided a stereoscopic device. The stereoscopic device includes a sensor assembly for detecting a sequence of stereoscopic images of an object, a movement detector for detecting the movements of the sensor assembly relative to the object, and a processing unit connected to the sensor assembly and to the movement detector. The processing unit selects portions of the stereoscopic images, according to a signal received from the movement detector, thereby producing a visually stable sequence of display images.

In accordance with a further aspect of the present invention, there is thus provided a method for producing a stable sequence of stereoscopic images of an object. The method includes the steps of detecting a plurality of stereoscopic images, for each of the stereoscopic images, detecting the movements of the stereoscopic sensor assembly relative to the object, and for each the stereoscopic images, selecting a portion of each of the stereoscopic images, according to the respective movement. The stereoscopic images are detected by employing a stereoscopic sensor assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description taken in conjunction with the drawings in which:

FIG. **1** is a schematic illustration of a three dimensional object and a stereoscopic vision apparatus, constructed and operative in accordance with a preferred embodiment of the present invention;

FIG. **2** is a schematic illustration of a stereoscopic vision apparatus, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **3**A is a schematic illustration of a super-pixel, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **3**B is a schematic illustration of the super-pixel of FIG. **3**A and a lenticular element, constructed and operative in accordance with a another preferred embodiment of the present invention;

FIG. **3**C is a schematic illustration of a sensor array and a lenticular lens layer, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **4** is a schematic illustration of a super-pixel, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **5**A is a schematic illustration of a color super-pixel, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **5**B is a schematic illustration of the color super-pixel of FIG. **5**A, with a single lenticular element, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **5**C is a schematic illustration of the color super-pixel of FIG. **5**A, combined with three lenticular elements, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **6** is a schematic illustration of a sensor array and a lenticular lens layer, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **7**A is a schematic illustration of a method for operating the apparatus of FIG. **2**, operative in accordance with a further preferred embodiment of the present invention;

FIG. **7**B is an illustration in detail of a step of the method of FIG. **7**A;

FIG. **7**C is a schematic illustration of a sensor array and a lenticular lens layer, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **8** is a schematic illustration of a stereoscopic vision apparatus, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **9**A is a view in perspective of a section of light sensors, and a lenticular element, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **9**B is a view from the bottom of the lenticular element and the section of light sensors of FIG. **9**A;

FIG. **9**C is a view from the side of the lenticular element and the section of light sensors of FIG. **9**A;

FIG. **10** is a view in perspective of a section of light sensors, and a lenticular element, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **11** is a view in perspective of a sensor array and a lenticular lens layer, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **12**A is a schematic illustration of a detection apparatus, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **12**B is another schematic illustration of the detection apparatus of FIG. **12**A;

FIG. **13** is a schematic illustration of a detection apparatus, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **14**A is a partially schematic partially perspective illustration of a combined illumination and detection device, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **14**B is a partially schematic partially perspective illustration of the combined illumination and detection device of FIG. **14**A, a controller and output frames, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **15** is an illustration in perspective of a color illumination unit, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **16** is a view in perspective of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **17** is a view in perspective of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **18** is a schematic illustration of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with another preferred embodiment of the present invention;

FIG. **19** is a schematic illustration of a sensor array and a partial lenticular lens layer, constructed and operative in accordance with a further preferred embodiment of the present invention;

FIG. **20**A is a schematic illustration of a system, for producing a color stereoscopic image, in a right side detection mode, constructed and operative in accordance with another preferred embodiment of the invention;

FIG. **20**B is an illustration of the system of FIG. **20**A, in a left-side detection mode;

FIG. **21**A is a schematic illustration of a timing sequence, in which the controller of the system of FIG. **20**A synchronizes the operation of illumination unit, apertures and image detector of that same system;

FIG. **21**B is a schematic illustration of another timing sequence, in which the controller of FIG. **20**A synchronizes the operation of the illumination unit, right and left apertures and the image detector;

FIG. 22 is a schematic illustration of a method for operating the system of FIGS. 20A and 20B, operative in accordance with a further preferred embodiment of the present invention;

FIG. 23 is a schematic illustration of a timing scheme, for operating the system of FIGS. 20A and 20B, in accordance with another preferred embodiment of the present invention;

FIG. 24 is a schematic illustration of a timing scheme, for operating the system of FIGS. 20A and 20B, in accordance with a further preferred embodiment of the present invention;

FIG. 25A is a schematic illustration of an object and a sensor assembly, when the sensor assembly is located at an initial position with respect to the object;

FIG. 25B is a schematic illustration of the object and the sensor assembly of FIG. 25A, when the sensor assembly has moved to a new position;

FIG. 25C is a schematic illustration of the object and the sensor assembly of FIG. 25A, when the sensor assembly has moved to another position;

FIG. 25D is a schematic illustration of the object and the sensor assembly of FIG. 25A, when the sensor assembly has moved to a further new position;

FIG. 25E is a schematic illustration of the object and the sensor assembly of FIG. 25A, when the sensor assembly has moved to another new position;

FIG. 25F is a schematic illustration of the object and the sensor assembly of FIG. 25A, when the sensor assembly has moved to a further new position;

FIG. 26A is a schematic illustration of a detected image, as detected by sensor assembly of FIG. 25A, and a respective displayed image, in accordance with a further preferred embodiment of the present invention;

FIG. 26B is a schematic illustration of a detected image, as detected by sensor assembly of FIG. 25B, and a respective displayed image;

FIG. 26C is a schematic illustration of a detected image, as detected by the sensor assembly of FIG. 25C, and a respective displayed image;

FIG. 27A is a schematic illustration of a sub-matrix, in accordance with another preferred embodiment of the present invention, when the sensor assembly is at a location illustrated in FIG. 25A;

FIG. 27B is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in FIG. 25B;

FIG. 27C is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in FIG. 25C;

FIG. 27D is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in FIG. 25D;

FIG. 27E is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in FIG. 25E; and

FIG. 27F is a schematic illustration of a sub-matrix, when the sensor assembly is at a location illustrated in FIG. 25F.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention overcomes the disadvantages of the prior art by providing a continuous vision stereoscopic apparatus, using a generally lenticular lens layer, a light sensor array and an image processing system.

Reference is now made to FIG. 1, which is a schematic illustration of a three dimensional object and a stereoscopic vision apparatus, generally referenced **100**, constructed and operative in accordance with a preferred embodiment of the present invention. Apparatus **100** includes a lenticular lens layer **104**, a light sensor array **102**, a processor **106** and two display devices **108**R and **108**L. Apparatus **100** is placed in front of a three-dimensional object **150**. An optical assembly **152** is placed between apparatus **100** and object **150**, for focusing the image of object **150** on light sensor array **102**.

Is Light sensor array **102** includes a plurality of sensors **110**, **111**, **112**, **113**, **114**, **115**, **116**, **117**, **118** and **119**. Lenticular lens layer **104** includes a plurality of lenticular elements **130**, **132**, **134**, **136** and **138**. Each one of the lenticular elements is located above two light sensors, in a way that lenticular element **130** is located above sensors **110** and **111**, lenticular element **132** is located above sensors **112** and **113**, lenticular element **134** is located above sensors **114** and **115**, lenticular element **136** is located above sensors **116** and **117** and lenticular element **138** is located above sensors **118** and **119**.

The light sensors **110**, **111**, **112**, **113**, **114**, **115**, **116**, **117**, **118**, and **119**, detect light as directed by the lenticular lens elements **130**, **132**) **134**, **136** and **138**, and provide respective information to the processor **106**. The processor **106** processes this information, produces a pair of images, as will be explained in detail herein below, and provides them to the display units **108**R and **108**L, which in turn produce visual representations of these images.

In general, each lenticular element directs light rays, which arrive from a predetermined direction to a predetermined location, and light rays which arrive from another predetermined direction, to another predetermined location. Hence, the present invention, utilizes the lenticular lens layer to distinguish between a right view image and a left view image, as is described herein below.

Each of the display units **108**R and **108**L includes a plurality of display units also known as pixels. Display unit **108**L includes pixels **142**A, **142**B, **142**C, **142**D and **142**E. Display unit **108**R includes pixels **144**A, **144**B, **144**C, **144**D and **144**E. Using these pixels each of the display units **108**R and **108**L produces an image, according to data provided from the processor **106**. The two images, each viewed by a different eye of the user, produce a sensation of a three dimensional image.

Light rays **124**A, and **126**A represent a right-side image of the three-dimensional object **150**. Light rays **120**A, and **122**A represent a left side image of the three-dimensional object **150**. The optical assembly **152** redirects light rays **120**A, **122**A, **124**A and **126**A so as to focus them on a plain which is determined by the light sensor array **102**, as light rays **120**B, **122**B, **124**B and **126**B, respectively. Hence, light rays **122**B and **126**B represent a focused right side view of the three-dimensional object **150**, and light rays **120**B and **1248** represent a focused left side view of the three-dimensional object **150**.

The lenticular lens layer **104** directs the focused right side view light rays **122**B and **126**B to light sensors **110** and **118**, respectively, as respective light rays **122**C and **126**C. In addition, the lenticular lens layer **104** directs the focused left side view light rays **120**B and **124**B to light sensors **111** and **119**, respectively. In general, light sensors **111**, **113**, **115**, **117** and **119** detect light rays which relate to a left side view image of object **150**, and light sensors **110**, **112**, **114**, **116**, and **118**, detect light rays which relate to a right side view image of object **150**.

Hence, light sensors **110**, **112**, **114**, **116** and **118** detect the right side image of object **150**, while light sensors **111**, **113**, **115**, **117** and **119** detect the left side image of object **150**. The light sensor array **102** provides data relating to the detected light intensity at each of the light sensors to the processor **106**.

The processor **106** processes this data, produces a right side image from the data relating to the right side view and a Jeff side image from the data relating to the left side view, and provides the respective image to the respective display unit **108**R and **108**L. In the present example, the processor **106** utilizes the data received from sensors **110**, **112**, **114**, **116** and **118** to determine the data provided to pixels **144**A, **144**B, **144**C, **144**D and **144**E, respectively. Similarly, the processor **106** utilizes the data received from sensors **111**, **113**, **115**, **117** and **119** to determine the data which is to be provided to pixels **142**A, **142**B, **142**C, **142**D and **142**E, respectively.

According to the present invention, the right side image and the left side image are detected at the same time and hence, can also be displayed at the same time. According to another aspect of the present invention, each of the light sensors **110**, **111**, **112**, **113**, **114**, **115**, **116**, **117**, **118**, and **119**, includes a plurality of color sensing elements, which together cover a predetermined spectrum, as will be described in detail herein below.

Reference is now made to FIG. **2**, which is a schematic illustration of a stereoscopic vision apparatus, generally referenced **200**, constructed and operative in accordance with another preferred embodiment of the present invention. Apparatus **200** includes a sensor assembly **202**, an interface **210**, a processor **208**, a movement detector **230**, a light source **206**, a memory unit **204**, a stereoscopic video generator **212** and a stereoscopic display **214**. The sensor assembly **202** is connected to the interface **210** by a flexible cord **218**. The interface **210** is connected to processor **208**, memory unit **204**, and to light source **206**. The processor **208** is further connected to the memory unit **204**, movement detector **230** and to the stereoscopic video generator **212**. The stereoscopic video generator **212** is further connected to the stereoscopic display **214**. Movement detector **230** detects the movement of sensor assembly **202** relative to an object. For this purpose, movement detector **230** is attached to sensor assembly **202**. In the case of a rigid endoscope, the movement detector **230** can be attached to any part of the endoscope rod (not shown), since the movement of the endoscope head can be determined according to the movement of any point of the endoscope rod. The operation of system **200**, according to data received from movement detector **230**, is described herein below.

The sensor assembly **202** includes a focusing element, which in the present example is a lens **226**, a lenticular lens layer **222**, a light sensor array **220**, an interface **228** and a light projecting means **224**. The lenticular lens layer **222** is attached to the light sensor array **220**. According to the invention, the light sensor array **220** can be any type of sensing array, such as a CCD detector, a CMOS detector, and the like. The light sensor array **220** is connected to the interface **228**, which can also acts as a supporting base.

The stereoscopic display **214** includes two display units, a left display unit **216**L (for placing in front of the left eye of the user) and a right display unit **216**R (for placing in front of the right eye of the user). Hence, the stereoscopic display **214** is capable of displaying stereoscopic images continuously. Such a stereoscopic display unit is for example the ProView 50 ST head-mounted display, manufactured and sold by Kaiser Electro-Optics Inc., a US registered company, located in Carlsbad, Calif. Another example for a stereoscopic display unit is the virtual retinal display (VRD) unit, which is provided by MICROVISION Inc., a US registered company, located in Seattle, Wash. It is noted that any method, which is known in the art for displaying stereoscopic, and for that matter three-dimensional images, is applicable for the present invention.

The image received from a three-dimensional object is received at the sensor assembly **202**, focused by lens **226**, optically processed by the lenticular lens layer **222** and finally detected by the light sensor array **220**. The lenticular lens layer **222** directs light coming from one predetermined direction to predetermined light sensors of the light sensor array **220**, and light coming from another predetermined direction to other predetermined light sensors of the light sensor array **220**. Accordingly, light sensor array **220** detects two images of the same object, a right side image and a left side image, each from a different direction. This aspect of the invention is described in detail hereinabove, in conjunction with FIG. **1**.

An electronic representation of this information is partially processed by the interface **228** and then provided to the interface **210**, via flexible cord **218**. It is noted that flexible cord **218** includes digital communication linking means such as optic fibers or electrical wires, for transferring data received from light sensor array **220**, as well as light guiding conducting means for conducting light from light source **206** to the light projecting means **224**. According to the present invention, flexible cord **218** can be replaced with a rigid cord (not shown), if necessary.

The data received at interface **210** includes information, which relates to the two images and has to be processed so as to distinguish them from each other. As the processor **208** processes the information, it uses the memory unit **204** as temporarily storage.

After processing the information, the processor **208** produces two matrices each being a reconstructed representation relating to one of the originally detected images. The processor provides these matrixes to the stereoscopic video generator **212**, which in turn produces two respective video signals, one for the left view image and another for the right view image.

The stereoscopic video generator **212** provides the video signals to the stereoscopic display **214**, which in turn produces two images, one using right display unit **216**R and another using left display unit **216**L.

It is noted that the general size of the sensor assembly **202** is dictated by the size of the sensor array and can be in the order of a few millimeters or a few centimeters. This depends on the size of each of the sensors in the array and the total number of sensors (i.e. the required optical resolution).

According to one aspect of the invention, each of the sensors in light sensor array **220**, is a full range sensor, which yields data relating to a gray scale stereoscopic image. According to another aspect of the invention, each of the sensors in the light sensor array, can be adapted so as to provide full color detection capabilities.

Reference is now made to FIG. **3**A, which is a schematic illustration of a super-pixel, generally referenced **300**, constructed and operative in accordance with a further preferred embodiment of the present invention. Super-pixel **300** includes a left section of sensors which includes three sensors **302**, **304** and **306**, and a right section of sensors which also includes three sensors **308**, **310** and **312**. Sensors **302** and **310** detect generally red colored light, sensors **304** and **312** detect generally green colored light and sensors **306** and **308** detect generally blue colored light. Hence, each of the sections includes a complete set of sensors for detecting light in the entire visible spectrum.

Reference is further made to FIG. **3**B, which is a schematic illustration of the super-pixel **300** of FIG. **3**A and a lenticular element, generally referenced **318**, constructed and operative in accordance with another preferred embodiment of the present invention. The lenticular element **318** is located on top of super-pixel **300**, where its right side covers the right section of the super-pixel **300**, and its left side covers the left section of the super-pixel **300**. Accordingly, the lenticular element **318** directs light, which arrives from the right (right view image), to the left section of the super-pixel **300**, where it is detected in full spectrum by sensors **302**, **304** and **306**.

The data provided by these sensors can later be utilized to reconstruct an image in full color. Similarly, the lenticular element **318** directs light, which arrives from the left (left view image), to the right section of the super-pixel **300**, where it is detected in full spectrum by sensors **308**, **310** and **312**.

Reference is now made to FIG. **3**C, which is a schematic illustration of a sensor array, generally referenced **330**, and a lenticular lens layer, generally referenced **332**, constructed and operative in accordance with a further preferred embodiment of the present invention. Sensor array **330** is; a matrix of M×N super-pixels, which are generally referenced **340**. For example, the upper left super-pixel is denoted $\mathbf{340}_{(1,1)}$, the last super-pixel in the same column is denoted $\mathbf{340}_{(1,N)}$ and the lower-right pixel is denoted $\mathbf{340}_{(M,N)}$. A lenticular lens layer **332** of which three lenticular elements are shown (referenced **334**), is placed over the sensor array **330**.

Lenticular element $\mathbf{334}_{(1)}$ covers the first column of super-pixels **340** from super-pixel $\mathbf{340}_{(1,1)}$ to super-pixel $\mathbf{340}_{(1,N)}$. Lenticular element $\mathbf{334}_{(2)}$ covers the second column of super-pixels **340** from super-pixel $\mathbf{340}_{(2,1)}$ to super-pixel $\mathbf{340}_{(2,N)}$. Lenticular element $\mathbf{334}_{(3)}$ covers the third column of super-pixels **340** from super-pixel $\mathbf{340}_{(3,1)}$ to super-pixel $\mathbf{340}_{(3,N)}$. Accordingly, each of the lenticular elements of the lenticular lens layer covers an entire column of super-pixels.

It is noted that a super-pixel according to the present invention can include sensors in any set of colors such as red-green-blue (RGB), cyan-yellow-magenta-green (CYMG), infra-red, ultra-violet, and the like, in any arrangement or scheme such as columns, diagonals, and the like. It is noted that such a set of colors can be achieved either by using specific color sensitive detectors or by using color filters over the wide spectrum detectors.

Reference is further made to FIG. **4**, which is a schematic illustration of a super-pixel, generally referenced **350**, constructed and operative in accordance with another preferred embodiment of the present invention. Super-pixel **350** includes a left section of sensors which includes four sensors **352**, **354**, **356** and **358** and a right section of sensors which also includes four sensors **360**, **362**, **364** and **366**. Sensors **352** and **366** detect generally cyan colored light, sensors **354** and **360** detect generally yellow colored light, sensors **356** and **362** detect generally magenta colored light and sensors **358** and **364** detect generally green colored light. Hence, each of the sections includes a complete set of sensors for detecting light in the entire visible spectrum.

Reference is further made to FIGS. **5**A, **5**B and **5**C. FIG. **5**A is a schematic illustration of a super-pixel, generally referenced **370**, constructed and operative in accordance with a further preferred embodiment of the present invention. FIG. **5**B is a schematic illustration of super-pixel **370** combined with a single lenticular element, generally referenced **384**, constructed and operative in accordance with another preferred embodiment of the present invention. FIG. **5**C is a schematic illustration of super-pixel **370** combined with three lenticular elements, generally referenced **386**, constructed and operative in accordance with a further preferred embodiment of the present invention.

The color arrangement which is provided for super-pixel **370** is typical for vertical light detection arrays, where each column of sensors is coated with light filtering layer of a different color. As can be seen in FIG. **5**A, super-pixel **370** includes a plurality of light sensors **372**, **374**, **376**, **378**, **380** and **382**. Light sensors **372** and **378** are blue color range sensors. Light sensors **374** and **380** are green color range sensors. Light sensors **376** and **382** are red color range sensors.

Reference is now made to FIG. **6**, which is a schematic illustration of a sensor, generally referenced **390**, and a lenticular lens layer, generally referenced **392**, constructed and operative in accordance with another preferred embodiment of the present invention. Sensor **390** is logically divided into a plurality of super-pixels, generally referenced $\mathbf{394}_{(x,y)}$ For example, the upper-left super-pixel is referenced $\mathbf{394}_{(1,1)}$ and the lower-right side super-pixel is referenced $\mathbf{394}_{(M,N)}$.

As can be seen from FIG. **6**, the color arrangement of sensor **390** is diagonal. Hence, each super pixel has a different color arrangement, and generally speaking, there are several types of super-pixels, such as red-blue (super pixel $\mathbf{394}_{(M-2,N)}$), green-red (super pixel $\mathbf{394}_{(M-1,N)}$) and blue-green (super pixel $\mathbf{394}_{(M,N)}$).

Reference is now made to FIG. **7**A, which is a schematic illustration of a method for operating apparatus **200**, operative in accordance with a further preferred embodiment of the present invention. In step **400**, the apparatus **200** splits light which arrives from different directions, utilizing the lenticular lens **222**. Each of the lenticular elements produces two light sectors, one sector which includes light rays arriving from the left side, and another sector which includes light rays arriving from the right side.

In step **402**, the apparatus detects each light sector separately, using a plurality of light detectors, each detecting a portion of its respective sector. With reference to FIG. **3**B, sensors **302**, **304** and **306** detect light which arrives from the lenticular element **318**, at the left side sector and sensors **308**, **310** and **312** detect light which arrives from the lenticular element **318**, at the right side sector. Each of the sensors detects light at a sub-sector.

In step **404**, the apparatus **200** determines the light characteristics as detected by each of the light sensors, at each of the sub-sectors. In step **408**, the apparatus **200** utilizes the data, which was accumulated from selected sub-sectors to determine and produce an image representing a view from one side. In step **406**, the apparatus **200** utilizes the data, which was accumulated from other selected sub-sectors to determine and produce an image representing a view from another side. In step **410**, the apparatus **200** displays both images using a continuous stereoscopic display device.

According to a further aspect of the invention, information from selected pixels can be used to enhance information for other pixels. For example, color information of pixels, which are associated with a first color, is used for extrapolating that color at the location of another pixel, associated with a second color.

Reference is further made to FIGS. **7**B and **7**C. FIG. **7**B is an illustration in detail of step **406** of FIG. **7**A. FIG. **7**C is a schematic illustration of a sensor array, generally referenced **450**, and a lenticular lens layer, generally referenced **452**, constructed and operative in accordance with another preferred embodiment of the present invention. Sensor array **450** includes a plurality of pixel sensors, referenced **454**, each associated with a selected color. For example, pixel sensors $R_{(1,1)}$, $R_{(2,2)}$, $R_{(3,3)}$, $R_{(4,4)}$, $R_{(1,4)}$ and $R_{(4,1)}$ are associated with the red color. Pixel sensors $G_{(2,1)}$, $G_{(3,2)}$, $G_{(4,3)}$, $G_{(1,3)}$ and $G_{(2,4)}$ are associated with the green color. Pixel sensors $B_{(1,2)}$, $B_{(2,3)}$, $B_{(3,4)}$, $B_{(3,1)}$ and $B_{(4,2)}$ are associated the blue color.

In step **420**, the system, according to the invention, selects a pixel sensor, associated with a first color. With reference to FIG. **7**C, the selected pixel sensor according to the present example is pixel sensor $R_{(3,3)}$.

In step **422**, the system determines pixels, associated with a second color, in the vicinity of the selected pixel. It is noted that these pixels can also be restricted to ones, which relate to the same image side of the selected pixel. With reference to FIG. **7**C, the second color is green and the green pixel sensors, in the vicinity of pixel sensor $R_{(3,3)}$, respective of the same image side are pixel sensors $G_{(5,1)}$, $G_{(3,2)}$, $G_{(3,5)}$, $G_{(5,4)}$, and $G_{(1,3)}$.

In step **424**, the system calculates an approximation of the level of the green color at the location of the selected pixel $R_{(3,3)}$. It is noted that the calculation can include a plurality of approximation procedures, such as calculating the weighted average level, depending on the location of pixel sensors $G_{(5,1)}$, $G_{(3,2)}$, $G_{(3,5)}$, $G_{(5,4)}$, and $G_{(1,3)}$, with respect to the location of the selected pixel sensor $R_{(3,3)}$. Similarly, blue color level at the location of the selected pixel sensor $R_{(3,3)}$, can be calculated using the information received from pixel sensors $B_{(1,2)}$, $B_{(1,5)}$, $B_{(3,1)}$, $B_{(3,4)}$ and $B_{(5,3)}$. Hence the present invention provides a method for enhancing picture resolution by means of color information interpolation, using image processing.

It is noted that none of the lenticular elements is necessarily round shaped, but can be formed according to other optical structures which are based on various prism designs, and the like, which provide the directing of beams of light coming from different directions to different directions.

Reference is now made to FIG. **8**, which is a schematic illustration of a stereoscopic vision apparatus, generally referenced **500**, constructed and operative in accordance with a further preferred embodiment of the present invention. Apparatus **500** includes a sensor assembly **502**, a frame grabber **510**, a processor **508**, a light source **506**, a memory unit **504**, a stereoscopic video generator **512** and a stereoscopic display **514**. The sensor assembly **502** is connected to the frame grabber **510** by a flexible cord **518**. The frame grabber **510**, the processor **508**, the memory unit **504** and the stereoscopic video generator **512** are all interconnected via a common bus.

The sensor assembly **502** is generally similar to the sensor assembly **202**, as described herein above in conjunction with FIG. **2**. The sensor assembly **502** includes a lens **526**, a lenticular lens layer **522**, a light sensor array **520**, an analog to digital converter (AND) **528** and a light projecting means **524**. The lenticular lens layer **522** is attached to the light sensor array **520**. Light sensor array **520** is connected to the A/D **528**, which could also act as a supporting base. The light projecting means **524** is connected to light source **506**, which provides light thereto.

The stereoscopic display **514** includes two display units, a left display unit **516**L (for placing in front of the left eye of the user), and a right display unit **516**R (for placing in front of the right eye of the user). Hence, the stereoscopic display **514** is capable of displaying stereoscopic images continuously. A/D converter **528** converts analog information received from light sensor array **522** into digital format and provides the digital information to frame grabber **510**.

The digital information is received by the frame grabber **510** and hence made available to the processor **508** via the bus. As the processor **508** processes the information, it uses the memory unit **504** as temporary storage. After processing the information, the processor **508** produces two matrices each being a reconstructed representation relating to one of the originally detected images. The processor **508** provides these matrices to the stereoscopic video generator **512**, which in turn produces two respective video signals, one for the left view image and another for the right view image. The stereoscopic video generator **512** provides the video signals to the stereoscopic display **514**, which in turn produces two images, one using right display unit **516**R and another using left display unit **516**L.

Reference is now made to FIGS. **9**A, **9**B and **9**C. FIG. **9**A is a view in perspective of a super-pixel, generally referenced **550**, and a lenticular element, generally referenced **552**, constructed and operative in accordance with another preferred embodiment of the present invention. FIG. **9**B is a view From the bottom of the lenticular element **552** and the super-pixel **550** of FIG. **9**A. FIG. **9**C is a view from the side of the lenticular element **552** and the super-pixel **550** of FIG. **9**A.

The super-pixel **550** includes four sensor sections, **554**, **556**, **558** and **560**, arranged in a rectangular formation. The lenticular element **552** is shaped like a dome and is basically divided into four sections, each facing a different one of the sensor sections **554**, **556**, **558** and **560**.

The super-pixel **550** and the lenticular element **552** form together, an optical detection unit, which is capable of detecting and distinguishing light which arrives from four different directions. The lenticular element **552** directs a portion of the upper-left side view of the detected object to sensor section **554** and directs a portion of the lower-left side view of the detected object to sensor section **556**. In addition, the lenticular element **552** directs a portion of the upper-right side view of the detected object to sensor section **560** and a portion of the lower-right side view of the detected object to sensor section **558**.

It is noted that according to a further aspect of the invention, the four-direction arrangement, which is described in FIGS. **9**A, **9**B and **9**C can be used to logically rotate the image which is provided to the user, without physically rotating the device itself. At first, sensor sections **560** and **558** are used to form the right-side image and sensor sections **554** and **556** are used to form the left-side image. A rotation at an angle of 90° clockwise, is provided by assigning sensor sections **554** and **560**, to form the right side image, and assigning sensor sections **556** and **558**, to form the left-side image. It is further noted that a rotation in any desired angle can also be performed by means of a linear or other combination of sensor sections, when reconstructing the final images.

Reference is now made to FIG. **10**, which is a view in perspective of a section of light sensors, generally referenced **570**, and a lenticular element, generally referenced **572**, constructed and operative in accordance with a further preferred embodiment of the present invention. Lenticular element **572** is extended to cover the entire area of the section of pixels, so as to enhance light transmission thereto.

Reference is now made to FIG. **11**, which is a view in perspective of a sensor array, generally referenced **580**, and a lenticular lens layer, generally referenced **582**, constructed and operative in accordance with another preferred embodiment of the present invention. The lenticular lens layer **582** includes a plurality of four direction lenticular elements such as described in FIGS. **9**A and **10**. The sensor array **580** is logically divided into a plurality of sensor sections, generally referenced $\mathbf{584}_{(x,y)}$. For example, the upper left sensor section is referenced $\mathbf{584}_{(1,1)}$ and the lower-right sensor section is referenced $\mathbf{584}_{(M,N)}$. Each of the sensor sections is located beneath a lenticular element and detects light directed thereby.

Reference is now made to FIGS. **12**A and **12**B. FIG. **12**A is a schematic illustration of a detection apparatus, generally referenced **600**, constructed and operative in accordance with a further preferred embodiment of the present invention. FIG. **12**B is another schematic illustration of detection apparatus **600**, of FIG. **12**A.

Detection apparatus **600** includes an optical assembly **602**, a lenticular lens layer **604** and an array of sensors **608**. The detection apparatus **600** detects images of an object **610**, which includes a plurality of object sections **610**A, **610**B, **610**C and **610**D.

Sensor array **608** includes a plurality of super-pixels **608**A, **608**B, **608**C and **608**D. Each of these super-pixels is divided into a left-side section and a right-side section. For example, super-pixel **608**A includes a left-side section, designated **608**A_L and a right-side section, designated **608**A_R.

The optical assembly **602** is divided into two optical sections **602**$_L$ and **602**$_R$, each directed at transferring an image, which represents a different side view. Optical section **602**$_R$ transfers an image, which is a view from the right side of object **610**. Optical section **602**$_L$ transfers an image, which is a view from the left side of object **610**.

A plurality of light rays **612**, **614**, **616** and **618** are directed from all sections of the object **610** to the left side of optical assembly **602** (i.e., optical section **602**$_L$), and are directed to the lenticular lens layer **604**. Here, these rays are further directed to the left-side view associated sensor sections, which are sensor sections **608**$_L$ (i.e., sensor sections **608**A_L, **608**B_L, **608**C_L and **608**D_L).

With reference to FIG. **12**B, a plurality of light rays **622**, **624**, **626** and **628** are directed from all sections of the object **610** to the right side of optical assembly **602** (i.e., optical section **602**$_R$), and are directed to the lenticular lens layer **604**. Here, these rays are further directed to the right-side view associated sensor sections, which are sensor sections **608**A_R, **608**B_R, **608**C_R and **608**D_R.

Reference is now made to FIG. **13**, which is a schematic illustration of a detection apparatus, generally referenced **630**, constructed and operative in accordance with another preferred embodiment of the present invention. Detection apparatus **630** includes an optical assembly, which is divided into four sections **632**, **634**, **636** and **638**, a lenticular lens layer **642** and an array of sensors **640**. The detection apparatus **630** detects images of an object **648**, which includes a plurality of object sections **648**A, **648**B, **648**C, **648**D, **648**E and **648**F. Light rays, which arrive from object **648** to any of the optical sections, are directed to a lenticular element of the lenticular lens layer **642**, according to their origin.

In the present example, all of the light rays **646**A, **646**B, **646**C and **646**D arrive from object element **648**A. Each of these rays is received at a different optical section. Ray **646**A is received and directed by optical section **636**, ray **646**B is received and directed by optical section **638**, ray **646**C is received and directed by optical section **634** and ray **646**D is received and directed by optical section **632**. Each of the optical sections directs its respective ray to a specific lenticular element **642**$_{(1,1)}$, at the right side of the lenticular lens layer **642**. The location of lenticular element **642**$_{(1,1)}$ is respective of the location of the object element **648**A. The lenticular element **642**$_{(1,1)}$ directs each of the rays to predetermined light sensors within its respective super-pixel **640**$_{(1,1)}$.

In accordance with a further aspect of the present invention, there is provided a reduced size color stereovision detection system, which uses time-multiplexed colored light projections, and respective time-multiplexed frame grabbing.

Reference is now made to FIGS. **14**A and **14**B. FIG. **14**A is a partially schematic, partially perspective illustration of a combined illumination and detection device, generally referenced **650**, constructed and operative in accordance with a further preferred embodiment of the present invention. FIG. **14**B is a partially schematic, partially perspective illustration of the combined illumination and detection device **650** of FIG. **14**A, a controller, generally designated **662**, and output frames, constructed and operative in accordance with another preferred embodiment of the present invention.

Device **650** includes a lenticular lens layer **652**, a full spectrum sensor array **654**, an optical assembly **660** and an illuminating unit **656**, surrounding the optical assembly **660**. Illuminating unit **656** includes a plurality of illuminating elements, generally referenced **658**, each being of a specific predetermined color. Illuminating elements **658**$_{RED}$ produce generally red light, illuminating elements **658**$_{GREEN}$ produce generally green light and illuminating elements **658**$_{BLUE}$ produce generally blue light. It is noted that each of the illuminating elements can be of a specific color (i.e., a specific wavelength), a range of colors (i.e., a range of wavelengths) or alternating colors, for example, a multi-color light emitting diode (LED).

Each group of illuminating elements, which are of the same color, is activated at a different point in time. For example, illuminating elements **658**$_{RED}$ are activated and shut down first, illuminating elements **658**$_{GREEN}$ are activated and shut down second and illuminating elements **658**$_{BLUE}$ are activated and shut down last. Then the illuminating sequence is repeated.

With reference to FIG. **14**B, the controller **662** is connected to the sensor array **654** and to the illuminating unit **656**. The sensor array **654** includes full spectrum sensors, which are capable of detecting red, green and blue light, but cannot indicate the wavelength of the detected light. The controller **662** associates the images, which are detected at any particular moment, using the sensor array **654**, with the color of the illuminating elements, which were active at that particular moment.

Hence, the first detected frame **664** in an illumination sequence is considered red, since the illuminating elements which were active at that time, were illuminating elements **658**$_{RED}$. Similarly, the second detected frame **666** in an illumination sequence is considered green, since the illuminating elements, which were active at that time, were illuminating elements **658**$_{GREEN}$. Finally, the last detected frame **668** in an illumination sequence is considered blue, since the illuminating elements, which were active at that time, were illuminating elements **658**$_{BLUE}$. It is noted that any other combination of colors is applicable for this and any other aspect of the present invention, such as CYMG, and the like.

Reference is now made to FIG. **15**, which is an illustration in perspective of a color illumination unit, generally referenced **670**, constructed and operative in accordance with a further preferred embodiment of the present invention. Unit **670** includes a light-guiding element **671**, which is generally shaped as an open-cut hollow cone, having a narrow section **674** and a wide section **672**. A detection head according to the invention, such as described in FIG. **2** (referenced **202**), can be placed within the hollow space of the light-guiding element **671**. A multi-color light source **680** can be connected to the narrow section **674**. Light, such as light ray **678**, which is emitted from the light source **680**, is directed via the light guiding element **671**, and is projected through the wide section **672**.

According to a further aspect of the invention, a remote multi-color light source **682** can be connected to the narrow section **674** via additional light guiding members such as optic-fibers **684**. Light, such as light ray **676**, which is emitted from the light source **682**, is directed via the light guiding members **684** to the narrow section **674**. The light-guiding element **671** guides light ray **676**, and projects it through the wide section **672**. This arrangement is useful when using an external light source, which is to be placed outside the inspected area (for example, outside the body of the patient).

According to a further aspect of the invention, a full spectrum illumination unit, which produces white light, is combined with a device such as sensor assembly **202** (FIG. **2**).

Reference is now made to FIG. **16**, which is a view in perspective of a sensor array, generally referenced **700**, and a partial lenticular lens layer, generally referenced **702**, constructed and operative in accordance with another preferred embodiment of the present invention. The partial Lenticular lens layer **700** includes a plurality of four direction lenticular elements **702** such as described in FIGS. **9**A and **10**. The sensor array **700** is logically divided into a plurality of sensor sections, generally referenced $\mathbf{704}_{(x,y)}$. For example, the upper left sensor section is referenced $\mathbf{704}_{(1,1)}$ and the lower-right sensor section is referenced $\mathbf{704}_{(M,N)}$. Some of the sensor sections, in the perimeter, are located beneath lenticular elements and others, such as the sensor sections in the center rectangle, which is defined by sensor sections $\mathbf{704}_{(4,3)}$-$\mathbf{704}_{(7,6)}$ are not. Accordingly, the sensors which are located at the center rectangle can not be used to provide multi-direction (stereoscopic or quadroscopic) information. Instead, these sensors provide enhanced resolution monoscopic information.

Reference is now made to FIG. **17**, which is a view in perspective of a sensor array, generally referenced **720**, and a partial lenticular lens layer, generally referenced **722**, constructed and operative in accordance with a further preferred embodiment of the present invention. The partial lenticular lens layer **720** includes a plurality of four direction lenticular elements such as described in FIGS. **9**A and **10**. The sensor array **720** is logically divided into a plurality of sensor sections, generally referenced $\mathbf{724}_{(x,y)}$. For example, the upper left sensor section is referenced $\mathbf{724}_{(1,1)}$ and the lower-right sensor section is referenced $\mathbf{724}_{(M,N)}$. Here, some of the sensor sections, in the center, (such as sensor section $\mathbf{724}_{(4,2)}$) are located beneath lenticular elements and others, such as the sensor sections in the perimeter (such as sensor section $\mathbf{724}_{(1,2)}$) are not. Accordingly, the sensors which are located at the center provide multi-direction (stereoscopic or quadroscopic) information and the ones in the perimeter provide enhanced resolution monoscopic information.

In accordance with a further aspect of the present invention there is provided a partial lenticular lens layer, which includes spaced apart lenticular elements. Reference is now made to FIG. **18**, which is a schematic illustration of a sensor array, generally referenced **740**, and a partial lenticular lens layer, generally referenced **742**, constructed and operative in accordance with another preferred embodiment of the present invention.

The partial lenticular tens layer **742** includes a plurality of lenticular elements designated $\mathbf{744}_{(1)}$, $\mathbf{744}_{(2)}$ and $\mathbf{744}_{(3)}$. Lenticular element $\mathbf{744}_{(1)}$ is located over the first two left columns of color sensors, generally referenced $\mathbf{746}_{(1)}$, of sensor array **740**. Hence, the information received from these first two left columns of color sensors of sensor array **740** contains stereoscopic information. The third and fourth columns of color sensors, generally designated $\mathbf{746}_{(2)}$, of sensor array **740** do not have a lenticular element located thereon, and hence, cannot be used to provide stereoscopic information.

Similarly, lenticular elements $\mathbf{744}_{(2)}$ and $\mathbf{744}_{(3)}$ are located over color sensor column pairs, $\mathbf{746}_{(3)}$ and $\mathbf{746}_{(5)}$, respectively, while color sensor column pairs, $\mathbf{746}_{(4)}$ and $\mathbf{746}_{(6)}$ are not covered with lenticular elements.

Reference is now made to FIG. **19**, which is a schematic illustration of a sensor array, generally referenced **760**, and a partial lenticular lens layer, generally referenced **762**, constructed and operative in accordance with another preferred embodiment of the present invention. Lenticular lens layer **762** includes a plurality of lenticular elements, referenced $\mathbf{764}_{(1)}$, $\mathbf{764}_{(2)}$, $\mathbf{764}_{(3)}$ and $\mathbf{764}_{(4)}$, being of different sizes and located at random locations over the sensor array **760**. It is noted that any structure of partial lenticular lens layer is applicable for the invention, whereas the associated image processing application has to be configured according to the coverage of that specific lenticular lens layer, and to address covered sensors and uncovered sensors appropriately.

In accordance with a further aspect of the present invention, there is provided a system, which produces a color stereoscopic image. The structure of the stereoscopic device defines at least two viewing angles, through which the detector can detect an image of an object. According to one aspect of the invention, the stereoscopic device includes an aperture for each viewing angle. Each of the apertures can be opened or shut. The stereoscopic device captures a stereoscopic image, by alternately detecting an image of an object, from each of the viewing angles, (e.g., by opening a different aperture at a time and shutting the rest) through a plurality of apertures, (at least two), each rime from a different aperture. The final stereoscopic image can be reconstructed from the images captured with respect to the different viewing angles.

The detection of stereoscopic color image is provided by illuminating the object with a sequence of light beams, each at a different wavelength, and detecting a separate image for each wavelength and aperture combination.

Reference is now made to FIGS. **20**A and **20**B. FIG. **20**A is a schematic illustration of a system, generally referenced **800**, for producing a color stereoscopic image, in a right side detection mode, constructed and operative in accordance with a further preferred embodiment of the invention. FIG. **20**B is an illustration of the system of FIG. **20**A, in a left-side detection mode.

System **800** includes a multiple aperture **804**, a controller **834**, an image detector **812**, a storage unit **836**, an image processor **838**, a movement detector **814** and an illumination unit **830**. The controller **834** is connected to the multiple aperture **804**, the image detector **812**, the storage unit **836**, movement detector **814** and to the illumination unit **830**. The storage unit **836** is further connected to the image processor **838**. The multiple aperture **804** includes a plurality of apertures, generally referenced $\mathbf{802}_i$, where each aperture can be activated to be open or closed. It is noted that when an aperture is open it is at least transparent to a predetermined degree to light, and when an aperture is closed, it substantially prevents the travel of light there through. Any type of controllable light valve can be used to construct each of the apertures Movement detector **814** detects the movement of image detector **812**. The detected movement can be a linear displacement, an angular displacement, and the derivatives thereof such as velocity, acceleration, and the like. The operation of system **800**, according to data received from movement detector **814**, is described herein below in connection with FIGS. **25**A, **25**B, **25**C, **26**A, **26**B and **26**C.

Light valve elements are components, which have an ability to influence light in at least one way. Some of these ways are, for example: scattering, converging, diverging, absorbing, imposing a polarization pattern, influencing a polarization pattern which, for example, may be by rotation of a polarization plane. Other ways to influence light can be by influencing wave length, diverting the direction of a beam, for example by using digital micro-mirror display (also known as DMD) or by using field effect, influencing phase, interference techniques, which either block or transfer a portion of a beam of light, and the like. Activation of light valve elements, which are utilized by the present invention, can be performed either electrically, magnetically or optically. Commonly used light valve elements are liquid crystal based elements, which either rotate or create and enforce a predetermined polarization axis.

In the present example, multiple aperture **804** includes two apertures **802**$_R$ and **802**$_L$. The controller **834** further activates the multiple aperture **804**, so as to alternately open apertures **802**$_R$ and **802**$_L$. In FIG. **20**A, aperture **802**$_R$ is open while aperture **802**$_L$ is closed and in FIG. **20**B, aperture **802**$_R$ is closed while aperture **802**$_L$ is open.

Light rays, which reflect from various sections of the object **810**, pass through the currently open aperture (**802**$_R$ in FIG. **20**A and **802**$_L$ in FIG. **20**B). Thereby, light rays **822** and **824** arrive from section **810**A of object **810**, pass through aperture **802**$_R$, and are detected by detection element **808**A, while light rays **826** and **828** arrive from section **810**D, pass through aperture **802**$_R$ and are detected by detection element **808**D. Hence, when aperture **802**$_R$ is open, the system **800** provides a right side view of the object **810**.

With reference to FIG. **20**B, when aperture **802**$_L$ is open, light rays **827** and **825** arrive from section **810**A, pass through aperture **802**$_L$, and are detected by detection element **808**A, while light rays **821** and **823** arrive from section **810**D, pass through aperture **802**$_L$, and are detected by detection element **808**D. Thereby, the system **800** provides a left side view of the object **810**.

The illumination unit **830** is a multi-color illumination unit, which can produce light at a plurality of wavelengths. The controller **834** provides a sequence of illumination commands to the illumination unit **830**, so as to produce a beam at a different predetermined wavelength, at each given moment. In the present example, the illumination unit is a red-green-blue (RGB) unit, which can produce a red light beam, a green light beam and a blue light beam. It is noted that illumination unit **830** can be replaced with any other multi-color illumination unit, which can produce either visible light, non-visible light or both, at any desired wavelength combination (CYMG and the like).

Furthermore, illumination unit **830** can be a passive unit, where it receives external commands to move from one wavelength to another, or it can be an active unit, which changes wavelength independently and provides an indication of the currently active wavelength to an external controller. Illumination unit **830** of the present example is a passive unit, which enhances the versatility of the system **800**, by providing any wavelength sequence on demand.

The image detector **812** includes a plurality of detection elements **808**A, **808**B, **808**C and **808**D. In accordance with one aspect of the invention, image detector **812** is a full range color detector, where each of the detection elements is operative to detect light in a plurality of wavelengths. In accordance with another aspect of the invention, the image detector **812** is a color segmented detector, where the detection elements are divided into groups, each operative to detect light in a different range of wavelengths. One conventional type of such detectors includes a full range detection array, which is covered by a color filter layer, where each detection element is covered by a different color filter. Accordingly, some of the detection elements are covered with red filters, others are covered with green filters and the rest are covered with blue filters.

The present invention enhances the color resolution of systems, using such color detectors. It will be appreciated by those skilled in the art that a color segment detector of poor quality may exhibit a wavelength (color) overlap between the different detection elements. For example, when the filters are of poor quality, their filtering functions tend to overlap such that the red filter also passes a small amount of either green or blue light. Hence, the detection element behind the red filter, also detects that small amount of green or blue light, but provides an output measurement as a measurement of red light. Hence, the color detector produces an image, which includes incorrect measurements of red light (e.g. more than the actual red light, which arrived at the detector) as result of that overlap. Accordingly, received information of the inspected object is not valid.

In the present invention, the illumination unit **830** produces a sequence of non-overlapping illumination beams at predetermined wavelengths (i.e., red, blue and green). As explained above, the color detector detects an image, which includes incorrect measurements, as a result of the wavelength (color) filtering overlap. Since the illumination unit **830** and the image acquisition process are synchronized, the imaging system can process each of the acquired images, according to the actual light beam color, which was produced therewith. For example, the illumination unit **830** produces blue light illumination beam. At the same time the image detector **812** detects an image, which also includes actual light measurements in detection elements, which are covered with green and red filters, due to the wavelength overlap. The imaging system can discard fight measurements, which are received from detection elements, covered with color filters, which are not blue (e.g., red and green).

Such sequenced color illumination of the object, provides enhanced color resolution, for color image detectors of poor quality, and obtains the valid color images of the inspected object. System **800** can further include a stereoscopic display unit (not shown), connected to controller **834** for displaying a stereoscopic image of object **810**.

Reference is further made to FIG. **21**A, which is a schematic illustration of a timing sequence, in which controller **834** (FIG. **20**A) synchronizes the operation of illumination unit **830**, apertures **802**$_L$ and **802**$_R$, and image detector **812**. Signal **840** represents the timing sequence of the left aperture **802**$_L$. Signal **842** represents the timing sequence of the right aperture **802**$_R$. Signal **844** represents the timing sequence of the blue light beam, produced by the illumination unit **830**. Signal **846** represents the timing sequence of the green light beam, produced by the illumination unit **830**. Signal **848** represents the timing sequence of the red light beam, produced by the illumination unit **830**. Signal **841** represents the timing sequence of the image detector **812**, where each image is downloaded therefrom.

Timing sequence **841** rises every time any of the rises of sequences **844**, **846** and **848** intersect with a rise of either sequence **842** or sequence **840**. For example, rise **841**$_A$ indicates a frame download of a blue light—right aperture combination, rise **841**$_B$ indicates a frame download of a green light—right aperture combination, and rise **841**$_C$ indicates a frame download of a red light—right aperture combination. Similarly, rise **841**$_D$ indicates a frame download of a blue light—left aperture combination, rise **841**$_E$ indicates a frame download of a green light—left aperture combination and rise **841**$_F$ indicates a frame download of a red light—left aperture combination.

It is noted that for some light sources, the produced light beams do not cover the full range of visible light. For such light sources, the missing color components can be reconstructed (interpolated) taking into consideration the physiological assumption, that color reflection response as a function of reflected angle, does not change much with angle.

Reference is further made to FIG. **22**, which is a schematic illustration of a method for operating system **800** of FIGS. **20**A and **20**B, operative in accordance with another preferred embodiment of the present invention. In step **870**, a sequence of illumination beams at predetermined wavelengths is produced. With reference to FIGS. **20**A and **20**B, controller **834** provides a sequence of illumination commands to the illumination unit **830**, which in turn produces different wavelength light beams, generally referenced **832**, at predetermined points in time, towards an object, generally referenced **810**.

In step **872** right and left apertures are alternated. Light rays, which reflect from various sections of the object **810**, pass through the currently open aperture ($\mathbf{802}_R$ in FIG. **20**A and $\mathbf{802}_L$ in FIG. **20**B). With reference to FIGS. **20**A and **20**B, controller **834** provides a sequence of operating commands to the apertures $\mathbf{802}_L$ and $\mathbf{802}_R$ In step **874**, a plurality of frames, each for a selected aperture and wavelength combination is detected. Controller **834** operates the image detector **812** so as to detect a plurality of frames, each respective of a selected aperture and wavelength combination.

Light rays **822** and **824** (FIG. **20**A) arrive from section **810**A of object **810**, pass through aperture $\mathbf{802}_R$, and are detected by detection element **808**A, while light rays **826** and **828** arrive from section **810**D, pass through aperture $\mathbf{802}_R$ and are detected by detection element **808**D. It is noted that in the present example, an imaging element (not shown) is introduced in the vicinity of multiple aperture **804**. Hence, when aperture $\mathbf{802}_R$ is open, the system **800** provides a right side view of the object **810**.

Light rays **827** and **825** (FIG. **20**B) arrive from section **810**A, pass through aperture $\mathbf{802}_L$ and are detected by detection element **808**A, while light rays **821** and **823** arrive from section **810**D, pass through aperture $\mathbf{802}_L$ and are detected by detection element **808**D. Hence, when aperture $\mathbf{802}_L$ is open, the system **800** provides a left side view of the object **810**.

With reference to FIG. **21**A, rise $\mathbf{841}_A$ provides a right side blue image (reference $\mathbf{806}^R{}_B$ of FIG. **20**A), rise $\mathbf{841}_B$ provides a right side green image (reference $\mathbf{806}^R{}_G$ of FIG. **20**A), and rise $\mathbf{841}_C$ provides a right side red image (reference $\mathbf{806}^R{}_R$ of FIG. **20**A). Similarly, rise $\mathbf{841}_O$ provides a left side blue image (reference $\mathbf{806}^L{}_B$ of FIG. **20**B), rise $\mathbf{841}_E$ provides a left side green image (reference $\mathbf{806}^L{}_G$ of FIG. **20**B), and rise $\mathbf{841}_F$ provides a left side red image (reference $\mathbf{806}^L{}_R$ of FIG. **20**B). With reference to FIGS. **20**A and **20**B, image detector **812** detects the plurality of frames, and provides right and left output video for image processing.

In step **876**, movement between the detector and the inspected organ, at selected frequencies is detected. This movement can be detected from movement of the endoscope, by means of a movement detector, or by analyzing the detected images, where different color images exhibit different lines, with dramatic color shade changes. This information is utilized in the following step, for spatially correlating between images of different colors.

In step **878** a stereoscopic color image from the plurality of frames, according to their aperture origin is produced. With reference to FIGS. **20**A and **20**B, the controller **834** stores the detected images in storage unit **836**. Image processor **838** retrieves the detected images from the storage unit **836**, and constructs color stereoscopic images. Hence, the present invention provides an additional way for detecting a color stereoscopic image, using a single image detector for both sides and all colors.

Reference is further made to FIG. **21**B, which is a schematic illustration of another timing sequence, in which controller **834** (FIG. **20**A) synchronizes the operation of illumination unit **830**, apertures $\mathbf{802}_L$ and $\mathbf{802}_R$, and image detector **812**. Signal **840'** represents the timing sequence of the left aperture $\mathbf{802}_L$. Signal **842'** represents the timing sequence of the right aperture $\mathbf{802}_R$. Signal **844'** represents the timing sequence of the blue light beam, produced by the illumination unit **830**. Signal **846'** represents the timing sequence of the green light beam, produced by the illumination unit **830**. Signal **848'** represents the timing sequence of the red light beam, produced by the illumination unit **830**. Signal **841'** represents the timing sequence of the image detector **812**, where each image is downloaded therefrom.

Timing sequence **841'** rises every time any of the rises of sequences **844'**, **846'** and **848'** intersects with a rise of either sequence **842'** or sequence **840'**. For example, rise $\mathbf{841'}_A$ indicates a frame download of a blue light—right aperture combination, rise $\mathbf{841'}_B$ indicates a frame download of a blue light—left aperture combination and rise $\mathbf{841'}_C$ indicates a frame download of a green light—right aperture combination. Similarly, rise $\mathbf{841'}_D$ indicates a frame download of a green light—left aperture combination, rise $\mathbf{841'}_E$ indicates a frame download of a red light—right aperture combination and rise $\mathbf{841'}_F$ indicates a frame download of a blue light—left aperture combination.

Reference is further made to FIG. **23**, which is a schematic illustration of a timing scheme, for operating system **800** of FIGS. **20**A and **20**B, in accordance with a further preferred embodiment of the present invention. Signal **850** represents the timing sequence of the left aperture $\mathbf{802}_L$. Signal **852** represents the timing sequence of the right aperture $\mathbf{802}_R$. Signal **854** represents the timing sequence of the blue light beam. Signal **856** represents the timing sequence of the green light beam. Signal **858** represents the timing sequence of the red light beam. Signal **851** represents the timing sequence of the image detector **812**, where each image is downloaded therefrom. As can be seen in FIG. **23**, the timing scheme is asymmetric, where the green light beam is activated for a time period which is twice the time period of either the red light beam or the blue light beam. Signal **851** corresponds to this arrangement and provides a green image download rise (references $\mathbf{851}_B$ and $\mathbf{851}_E$), after a time period which is twice as long with comparison to red image download rises (references $\mathbf{851}_C$ and $\mathbf{851}_F$) or blue image download rises (references $\mathbf{851}_A$ and $\mathbf{851}_D$).

Reference is further made to FIG. **24**, which is a schematic illustration of a timing scheme, for operating system **800** of FIGS. **20**A and **20**B, in accordance with another preferred embodiment of the present invention. Signal **860** represents the timing sequence of the left aperture $\mathbf{802}_L$. Signal **862** represents the timing sequence of the right aperture $\mathbf{802}_R$. Signal **864** represents the timing sequence of the magenta light beam. Signal **866** represents the timing sequence of the yellow light beam. Signal **868** represents the timing sequence of the cyan light beam. As can be seen in FIG. **24**, the timing scheme addresses an alternate wavelength scheme and is also asymmetric.

It is noted that a mechanical multi-wavelength illumination unit such as described in the prior art, can be used for implementing the present invention. However, such a system significantly reduces the capability of the user to control illumination duration, wavelength ratio and detection timing, such as described herein above.

The disclosed technique incorporates even more advanced aspects, which provide automatic image translation correction, based on correlation between the two detected images. When the endoscope is handheld, it is subjected to the vibration of the human hand, which is in the order of 10 Hz, at an angular amplitude of 1 degree. This phenomenon causes a blur of areas, where different colors intersect, and is also known as the "between color field blur" effect. It is noted that any movement between the image detector and the inspected organ can cause this phenomenon, provided it occurs at particular frequencies, defined by the structure and the manner of operation of the system.

With reference to FIGS. **20**A and **20**B, since the information retrieved from image detector **812** relates to specific colors, then controller **834** can correlate between such single color images to determine the ΔX and ΔY to the subsequent color, and hence compose and produce an un-blurred color image. Due to the vibrations of the human hand, while image detector **812** is substantially stationary relative to object **810**, the displayed stereoscopic image of object **810** is blurred. In order to mitigate this problem, and provide a blur-free stereoscopic image of object **810** to the viewer, movement detector **230** (FIG. **2**), is incorporated with system **200**, and movement detector **814** is incorporated with system **800**.

Reference is now made to FIGS. **25**A, **25**B, **25**C, **26**A, **26**B and **26**C and again to FIG. **2**. FIG. **25**A is a schematic illustration of an object, generally referenced **766**, and a sensor assembly generally referenced **768**, when the sensor assembly is located at an initial position with respect to the object. FIG. **25**B is a schematic illustration of the object and the sensor assembly of FIG. **25**A, when the sensor assembly has moved to a new position. FIG. **25**C is a schematic illustration of the object and the sensor assembly of FIG. **25**A, when the sensor assembly has moved to another position. FIG. **26**A is a schematic illustration of a detected image, generally referenced **770**, as detected by sensor assembly of FIG. **25**A, and a respective displayed image, generally referenced **772**, in accordance with a further preferred embodiment of the present invention. FIG. **26**B is a schematic illustration of a detected image, generally referenced **780**, as detected by sensor assembly of FIG. **25**B, and a respective displayed image, generally referenced **774**. FIG. **26**C is a schematic illustration of a detected image, generally referenced **782**, as detected by the sensor assembly of FIG. **25**C, and a respective displayed image, generally referenced **776**.

The foregoing description relates to one aspect of the invention, in which an stereoscopic image of an object is captured by a sensor array through a lenticular lens layer (i.e., each captured image includes all the primary colors of the color palette, such as RGB, CYMG, and the like). It is noted that the movement is determined such that it has a constant average (e.g., vibrating about a certain point).

With reference to FIGS. **25**A and **26**A, the center of sensor assembly **768** is located at a point O_1 relative to object **766**. Sensor assembly **768** detects detected image **770** (FIG. **26**A) of object **766**, where the detected image **770** is composed for example, of four hundred pixels (i.e., a 20×20 matrix). Each pixel is designated by $P_{m,n}$ where m is the row and n is the column of detected image **770**. For example, pixel $\mathbf{778}_{1,1}$ is located in the first row and the first column of detected image **770**, pixel $\mathbf{778}_{1,2}$ is located in the first row and the second column, and pixel $\mathbf{778}_{20,20}$ is located in row twenty and column twenty. Processor **208** selects pixels $\mathbf{778}_{3,3}$ through $\mathbf{778}_{18,18}$ (i.e., a total of 16×16–256 pixels) to display the sub-matrix **772** on stereoscopic display **214** (FIG. **2**), while the center of sensor assembly **768** is located at point O_1.

With reference to FIGS. **25**B and **26**B, due to the vibrations of the human hand, the center of sensor assembly **768** has moved to a point O_2 relative to object **766**. Point O_2 is located a distance ΔX_1 to the right of point O_1 and a distance ΔY_1 below point O_1. In this case the length of ΔX_1 is equal to the horizontal width of two pixels of detected image **780**, and the length ΔY_1 is equal to the vertical height of minus two pixels of detected image **780**. Movement detector **230** detects the movement of sensor assembly **768** from point O_1 to point O_2, and sends a signal respective of this movement, to processor **208**.

With reference to FIG. **26**B, the image of the object section that was captured by sub-matrix **772**, is now captured by a sub-matrix **774**, which is shifted two pixels up and two pixels to the left. Hence, displaying sub-matrix **774**, compensates for the movement of sensor assembly **768**. For this purpose, processor **208** selects pixels $\mathbf{778}_{1,1}$ through $\mathbf{778}_{16,16}$ of detected image **780**, for sub-matrix **774**. Despite the movement of sensor assembly **768**, the images of sub-matrices **772** and **774** are substantially of the same area, and therefore the user does not realize that sensor assembly **768** has moved from point O_1 to point O_2.

With reference to FIGS. **25**C and **26**C, the center of sensor assembly **768** has moved from point O_1 to a point O_3 relative to object **766**. Point O_3 is located a distance ΔX_2 to the left of point O_1 and a distance ΔY_2 above point O_1. In this case the length of ΔX_2 is equal to the horizontal width of minus two pixels of detected image **782**, and the length ΔY_2 is equal to the vertical height of one pixel of detected image **782**. Movement detector **230** detects the movement of sensor assembly **768** from point O_1 to point O_3, and sends a signal respective of this movement, to processor **208**.

With reference to FIG. **26**C, the image of the object section that was captured by sub-matrix **772**, is now captured by a sub-matrix **776**, which is shifted one pixel up and two pixels to the left. Hence, displaying sub-matrix **774**, compensates for the movement of sensor assembly **768** two pixels to the left and one pixel up. For this purpose, processor **208** selects pixels $\mathbf{778}_{5,4}$ through $\mathbf{778}_{20,19}$ of detected image **782**, for sub-matrix **776**. Despite the movement of sensor assembly **768**, the images of displayed images **772** and **776** are identical, and therefore the user does not realize that sensor assembly **768** has moved from point O_1 to point O_3. Therefore, by incorporating movement detector **230** with sensor assembly **768**, the viewer views a blur-free stereoscopic color image of object **766**, despite the vibrations of sensor assembly **768** caused by the human hand.

It is noted that processor **208** processes the detected images **780** and **782**, if the dimensions ΔX_1, ΔX_2, ΔY_1 and Y_2 are of the order of A, the amplitude of vibrations of the human hand and in the appropriate frequency. In general, processor **208** performs the compensation process, between a plurality of captured images, as long as the detected movement, is maintained about a certain average point ($X_{AVERAGE}$, $Y_{AVERAGE}$). When one of the average values $X_{AVERAGE}$ and $Y_{AVERAGE}$ changes, then processor **208** initiates a new compensation process around the updated average point, accordingly.

Reference is now made to FIGS. **25**D, **25**E, **25**F, **27**A, **27**B, **27**C, **27**D, **27**E, **27**F and again to FIGS. **20**A, **20**B, **25**A, **25**B and **25**C. FIG. **25**D is a schematic illustration of the object and the sensor assembly of FIG. **25**A, when the sensor assembly has moved to a further new position. FIG. **25**E is a schematic illustration of the object and the sensor assembly of FIG. **25**A, when the sensor assembly has moved to another new position. FIG. **25**F is a schematic illustration of the object and the sensor assembly of FIG. **25**A, when the sensor assembly has moved to a further new position. FIG. **27**A is a schematic illustration of a sub-matrix, generally referenced **1064**, in accordance with another preferred embodiment of the present invention, when the sensor assembly is at a location illustrated in FIG. **25**A. FIG. **27**B is a schematic illustration of a sub-matrix, generally referenced **1066**, when the sensor assembly is at a location illustrated in FIG. **25**B. FIG. **27**C is a schematic illustration of a sub-matrix, generally referenced **1068**, when the sensor assembly is at a location illustrated in FIG. **25**C. FIG. **27**D is a schematic illustration of a sub-matrix, generally referenced **1070**, when the sensor assembly is at a location illustrated in FIG. **25**D. FIG. **27**E is a schematic illustration of a sub-matrix, generally referenced **1072**, when the sensor assembly is at a location illustrated in FIG.

25E. FIG. 27F is a schematic illustration of a sub-matrix, generally referenced **1074**, when the sensor assembly is at a location illustrated in FIG. **25**F.

Image processor **838** (FIG. **20**A), selects each of sub-matrices **1064**, **1066** and **1068** from detected images **1052**, **1054** and **1056**, respectively, as described herein above in connection with FIGS. **26**A, **26**B and **26**C. Analogously, image processor **838** selects each of sub-matrices **1070**, **1072** and **1074** from detected images **1058**, **1060** and **1062**, respectively, when the center of sensor assembly **768** is directed to each of the points O_4, O_5, and O_6, respectively. For example, when the center of sensor assembly **768** is directed to point O_4, which is located to the right and above point O_1, image processor **838** selects sub-matrix **1070** (FIG. **27**D). When the center of sensor assembly **838** is directed to point O_5 directly below point O_1, image processor **838** selects sub-matrix **1072** (FIG. **27**E). When the center of sensor assembly **838** is directed to point O_6 directly above point O_1, image processor **838** selects sub-matrix **1074** (FIG. **27**F).

In the following description, object **810** (FIGS. **20**A and **20**B) and object **766** (FIG. **25**A) are used interchangeably, although they both represent the same object. Object **810** is described in connection with multiple aperture **804** and illumination unit **830**, while object **766** is described in connection with the location of sensor assembly **768** relative thereto. It is noted that during the time interval in which the opening of multiple aperture **804** switches from aperture $\mathbf{802}_R$ (FIG. **20**A), to aperture $\mathbf{802}_L$ (FIG. **20**B), sensor assembly **768** moves relative to object **766**, due to the vibrations of the human hand. Thus, for example, sub-matrix **1064** (FIG. **27**A) represents a right view image of object **810** corresponding to the image which image processor **838** captures, when aperture $\mathbf{802}_R$ is open. On the other hand, sub-matrix **1066** (FIG. **27**B) represents a left view image of object **766**, when aperture $\mathbf{802}_L$ is open.

Furthermore, the color of detected images **1052**, **1054**, **1056**, **1058**, **1060**, and **1062** changes as described herein above for example in connection with FIG. **21**B. Image processor **838** receives download image $\mathbf{841'}_A$, and selects sub-matrix **1064** (FIG. **27**A), which is a right view image of object **766** (FIG. **25**A) in blue, when the center of sensor assembly **768** is directed to point O_1.

While multiple aperture **804** switches to aperture $\mathbf{802}_L$, the center of sensor assembly **768** (FIG. **25**B) directs to point O_2 (FIG. **25**B), and image processor **838** receives download image $\mathbf{841'}_B$. Since the center of sensor assembly **768** is directed to point O_2 (FIG. **25**B), then image processor **838** selects sub-matrix **1066** (FIG. **27**B) which represents a left view image of object **810** in blue. Analogously, sub-matrix **1068** (FIG. **27**C) represents a green right view image of object **766** (download image $\mathbf{841'}_C$), when the center of sensor assembly **768** is directed to point O_3 (FIG. **25**C). Sub-matrix **1070** (FIG. **27**D) represents a green left view image of object **766** (download image $\mathbf{841'}_D$), when the center of sensor assembly **768** directs to point O_4 (FIG. **25**D). Sub-matrix **1072** (FIG. **27**E) represents a red right view image of object **766** (download image $\mathbf{841'}_E$), when the center of sensor assembly **768** directs to point O_5 (FIG. **25**E). Sub-matrix **1074** (FIG. **27**F) represents a red left view image of object **766** (download image $\mathbf{841'}_F$), when the center of sensor assembly **768** directs to point O_6 (FIG. **25**F).

According to FIG. **21**A, a stereoscopic display unit (not shown) displays sub-matrices **1064**, **1066**, **1068**, **1070**, **1072** and **1074** in sequence. Sub-matrices **1064**, **1068** and **1072** are the right side views of substantially the same area of object **766**, which together compose a right side color image of the object **766**. Sub-matrices **1066**, **1070** and **1074** are the left side views of substantially the same area of object **766**, which together compose a left side color image of the object **766**. The stereoscopic display unit alternately displays the right view image and the left view image of substantially the same area of object **766**. Thus, system **800** maintains a stable image of object **766**, which does not exhibit any change in the location of object **766** as displayed on the stereoscopic display unit, despite the movement of sensor assembly **768** due to the vibrations of the human hand.

For example, image processor **838** selects sub-matrices **1064**, **1068** and **1072** (FIGS. **27**A, **27**C and **27**E, respectively), and the stereoscopic display (not shown), sequentially displays the same image in blue, green and red, respectively. Thus, the stereoscopic display presents a stable right side image of the object in full color, to the right eye. Similarly, the stereoscopic display sequentially displays sub-matrices **1066**, **1070** and **1074** (FIGS. **27**B, **27**D and **27**F, respectively), wherein the color of each sub-matrix sequentially changes from blue to green to red, respectively. In this manner, the stereoscopic display presents a stable left side image of the object in full color, to the left eye. Thus, the user views a stable full color stereoscopic image of the object, despite the movement of the endoscope due to the vibrations of the human hand.

It is noted that an RGB timing scheme can be employed. In this case, the stereoscopic display displays the sub-matrices in a sequence of right-red, left-green, right-blue, left-red, right-green and left-blue.

It is noted that the sequence of FIGS. **27**A, **27**B, **27**C, **27**D, **27**E and **27**F is cyclically repeated during the imaging process of the object. Other timing schemes can be employed where the download image trigger signal is used for acquiring a reading from movement detector **814**, for the detected image. Examples for such timing schemes are illustrated in FIGS. **23**, **24**, and **21**A.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described here in above. Rather the scope of the present invention is defined only by the claims which follow.

The invention claimed is:

1. Stereoscopic device comprising:

a sensor assembly having an optical axis, for detecting a sequence of alternating stereoscopic images of an object;

a movement detector, detecting movements of said sensor assembly perpendicular to the optical axis, relative to said object, an average of said movements being constant and defining a location of origin; and

a processing unit connected to said sensor assembly and to said movement detector,

wherein said processing unit selects corresponding portions of said alternating stereoscopic images, according to a signal received from said movement detector and compensates for detected movements, thereby producing a visually stable sequence of display images;

wherein said visually stable sequence of display images comprises a plurality of sub-matrices, each one of said sub-matrices is selected from a respective one of said stereoscopic images, each one of said sub-matrices is located at a distance equal to a respective one of said movements from said location of origin, in a direction opposite to said respective movement, relative to said location of origin, and

wherein each one of said display images has a predetermined and constant area size, the area size being smaller than that of each of said detected stereoscopic images.

2. The stereoscopic device according to claim 1, wherein said sensor assembly comprises a lenticular lens layer and a light sensor array, wherein said lenticular lens layer is located in front of said light sensor array.

3. The stereoscopic device according to claim 2, wherein said light sensor array is a color red-green-blue (RGB) sensor array.

4. The stereoscopic device according to claim 2, wherein said light sensor array is a color cyan-yellow-magenta-green (CYMG) sensor array.

5. The stereoscopic device according to claim 1, wherein said processing unit comprises a processor connected to said movement detector and a memory unit connected to said processor.

6. The stereoscopic device according to claim 1, further comprising:

an interface connected to said sensor assembly and to said processor;

a light source connected to said interface;

a stereoscopic video generator connected to said processor; and

a stereoscopic display unit connected to said stereoscopic video generator, for producing said visually stable sequence of display images.

7. The stereoscopic device according to claim 6, wherein said light source produces light in a predetermined range of wavelengths.

8. The stereoscopic device according to claim 7, wherein said predetermined range of wavelengths is selected from the list consisting of substantially visible red color light;

substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

9. The stereoscopic device according to claim 6, wherein said light source produces at least two alternating beams of light, each said beams of light characterized as being in a different range of wavelengths.

10. The stereoscopic device according to claim 1, wherein said visually stable sequence of display images is stereoscopic.

11. The stereoscopic device according to claim 1, wherein said visually stable sequence of display images is partially stereoscopic.

12. The stereoscopic device according to claim 1, wherein said sensor assembly further comprises:

at least two apertures, each said apertures including a light valve, each said light valves being operative to open at a different predetermined timing; and

a multi wavelength light sensor array;

wherein said multi wavelength light sensor array detects said images, each one of said images corresponding to a predetermined combination of an open state of a selected one of said light valves and a selected one of at least two alternating beams of light.

13. The stereoscopic device according to claim 12, further comprising a controllable multi wavelength illumination unit, connected to said processing unit, said controllable multi wavelength illumination unit producing at least two alternating beams of light, each said beams of light characterized as being in a different range of wavelengths.

14. The stereoscopic device according to claim 13, wherein said controllable multi wavelength illumination unit produces at least two alternating beams of light, each said beams of light characterized as being in a difference range of wavelengths.

15. The stereoscopic device according to claim 13, wherein each said different ranges of wavelengths associated with said multi wavelength illumination unit, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

16. The stereoscopic device according to claim 12, further comprising capture means, connected to said multi wavelength light sensor array, for capturing data received from said multi wavelength light sensor array.

17. The stereoscopic device according to claim 16, wherein said processing unit further comprises:

an image processor;

a storage unit connected to said image processor, said storage unit capturing said capturing data; and

a controller connected to said storage unit, said movement detector, said light valves, and to said multi wavelength light sensor array, said controller timing the operation of said light valves, said multi wavelength light sensor array and said controllable multi wavelength illumination unit.

18. The stereoscopic device according to claim 17, further comprising:

a stereoscopic video generator connected to said image processor; and

a stereoscopic display unit connected to said stereoscopic video generator, for producing said visually stable sequence of display images.

19. The stereoscopic device according to claim 12, wherein said multi wavelength light sensor array includes at least two groups of sensors, wherein the sensors of each said group detect light in a different range of wavelengths.

20. The stereoscopic device according to claim 19, wherein each said different ranges of wavelengths associated with said sensors, is selected from the list consisting of:

substantially visible red color light;
substantially visible green color light;
substantially visible blue color light;
substantially visible cyan color light;
substantially visible yellow color light;
substantially visible magenta color light;
substantially infra-red light;
substantially ultra-violet light; and
visible light.

21. The stereoscopic device according to claim 12, wherein said multi wavelength light sensor array includes a plurality of sensors, each of said sensors detecting light in a predetermined range of wavelengths.

22. The stereoscopic device according to claim 12, wherein said multi wavelength light sensor array is a color red-green-blue (RGB) sensor array.

23. The stereoscopic device according to claim 12, wherein said multi wavelength light sensor array is a color cyan-yellow-magenta-green (CYMG) sensor array.

24. The stereoscopic device according to claim 12, wherein the color of each of said sub-matrices is selected from the list consisting of:

substantially visible red;
substantially visible green;
substantially visible blue;
substantially visible cyan;
substantially visible yellow; and
substantially visible magenta.

25. The stereoscopic device according to claim 1, wherein said alternating stereoscopic images alternate between a left image and a right image.

26. Method for producing a stable sequence of stereoscopic images of an object, the method comprising the steps of:

detecting a plurality of alternating stereoscopic images, using a stereoscopic sensor assembly having an optical axis;

for each said alternating stereoscopic images, detecting movements of said stereoscopic sensor assembly perpendicular to said optical axis relative to said object, an average of said movements is constant and defining a location of origin;

for each said stereoscopic images, selecting a corresponding portion of each of corresponding ones of said stereoscopic images, according to said respective movement, said corresponding portion being a sub-matrix of a respective one of said stereoscopic images, wherein each one of said sub-matrices is located at a distance equal to a respective one of said movements from said location of origin, in a direction opposite to said respective movement, relative to said location of origin, wherein said step of selecting further comprises a sub-procedure of measuring a distance of a respective one of said movements from said location of origin, in a direction opposite to said respective movement relative to said location of origin; and

compensating for said detected movements of said stereoscopic sensor assembly, thereby producing a visually stable sequence of display images, said visually stable sequence of display images comprises a plurality of said sub-matrices, wherein each one of said display images has a predetermined and constant area size smaller than an area size of each of said detected stereoscopic images.

27. The method according to claim 26, further comprising a preliminary step of illuminating a detected area of said object.

28. The method according to claim 27, wherein said stereoscopic sensor assembly comprises a lenticular lens layer and a light sensor array, wherein said lenticular lens layer is located in front of said light sensor array.

29. The method according to claim 28, wherein said step of illuminating comprises a procedure of sequentially illuminating said detected area, with alternating beams of light of different ranges of wavelengths.

30. The method according to claim 28, further comprising a step of associating each one of said sub-matrices in time, with the currently illuminating ranges of wavelengths.

31. The method according to claim 27, wherein said stereoscopic sensor assembly comprises:

at least two apertures, each said apertures including a light valve, each said light valves being operative to open at a different predetermined timing; and

a multi wavelength light sensor array,

wherein said multi wavelength light sensor array detects said images, each one of said images corresponding to a predetermined combination of an open state of a selected one of said light valves and a selected one of at least two alternating beams of light.

32. The method according to claim 31, wherein said step of illuminating comprises a procedure of producing at least two alternating beams of light, each said beams of light characterized as being in a different range of wavelengths.

33. The method according to claim 32, further comprising a step of associating each one of said sub-matrices, at said different predetermined timing, with said different range of wavelengths.

34. The method according to claim 26, wherein said alternating stereoscopic images alternate between a left image and a right image.

* * * * *